Garryaceae—Silktassel family

Garrya Dougl. ex Lindl.

silktassel

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Growth habit and occurrence. The genus *Garrya*—silktassel—consists of 14 New World species ranging from the Pacific Northwest to Panama (Dahling 1978). Only those in the United States and Mexico are considered here. *Garrya* is a highland genus occurring in chaparral and coniferous forests above lowland deserts, in semiarid regions, or in coastal or near-coastal conditions. Species may vary in size from low shrubs to trees (table 1). First discovered by David Douglas in the Pacific Northwest in 1826, Garrya was named in honor of Nicholas Garry, the first secretary of the Hudson Bay Company (Dahling 1978). Alternatively classified in Garryaceae and Cornaceae by various taxonomists, the genus will be classified as Garryaceae in this manual, after Dahling (1978) and Kartesz (1994).

Use. Wavyleaf and canyon silktassels and bearbrush are planted as ornamentals in many areas of the world (Dahling 1978). The graceful catkins and stately shape of these species make them desirable landscape shrubs. Introduced into cultivation between 1842 and 1902, silktassels have also been used for erosion control (Rehder 1940; Reynolds and Alexander 1974). Native plants are browsed by domestic livestock, deer (*Odocoileus* spp.), and bighorn sheep (*Ovis canadensis*) (Reynolds and Alexander 1974). Wavyleaf silktasssel will tolerate arid conditions, low fertility, sandy soils, and a wide range of pH values (Ridgeway 1973).

Although known to be toxic, stem extracts of laurel-leaf silktassel are used as an antidiarrhetic throughout rural Mexico, and bark extracts were reportedly used by Native Americans to treat fever (Dahling 1978). Ashy silktassel was used as a laxative and to treat colds, stomach aches, and gonorrhea by Kawaiisu Indians (Moerman 1986). Whole-plant extracts of ashy and wavyleaf silktassel plants native to Arizona have been found to contain gutta-percha, a natural rubber. This is the first reported occurrence in Garryaceae (Roth and others 1985).

Flowering and fruiting. Flowers are dioecious. Both appear in axillary or terminal catkinlike racemes in the spring (Reynolds and Alexander 1974); however male flowers are minute (Dahling 1978). Silktassels are well adapted for wind pollination. Several species hybridize, most notably bearbrush with ashy silktassel and eggleaf silktassel with laurel-leaf silktassel (Dahling 1978; Mulligan and Nelson 1980).

Silktassel fruits are persistent, 2-sided berries that appear green and fleshy when young but become dry and brittle at maturity (Dahling 1978) (figures 1–3). The fruit is globose to ovoid and relatively uniform among the species included here, averaging 7.2 mm long by 6.2 mm wide and producing from 1, 2, or (rarely) 3 seeds that are 2 to 3 mm in diameter (Dahling 1978).

Collection of fruits. Ripe fruits may be gathered by stripping them from the branches onto canvas, or hand-picking them from the bushes. Because the fruits may be infested with insect larvae, care must be taken to collect only sound fruits (Reynolds and Alexander 1974).

Extraction and storage of seeds. After twigs, leaves, and other debris have been sifted out, fruits are run through a macerator and the pulp and empty seeds floated off or screened out. Seeds may also be extracted by rubbing the fruits over a fine-mesh screen and floating off the pulp and empty seeds in water (Reynolds and Alexander 1974). Fifty kilograms (110 lb) of dry bearbrush berries yield about 25 kg (55 lb) of cleaned seeds. Cleaned seed densities range from 37,500 to 72,800 seeds/kg (17,000 to 33,000/lb). About 85 to 99% of the seeds will normally be sound (Reynolds and Alexander 1974). Storage methods suitable for most shrub species should also apply to silktassel seeds.

Pregermination treatments. Seeds of ashy silktassel and bearbrush will not germinate without pretreatment because of embryo dormancy (Mirov and Kraebel 1937; Reynolds and Alexander 1974). Some seeds of Wright silktassel exhibit embryo dormancy, whereas others germinate

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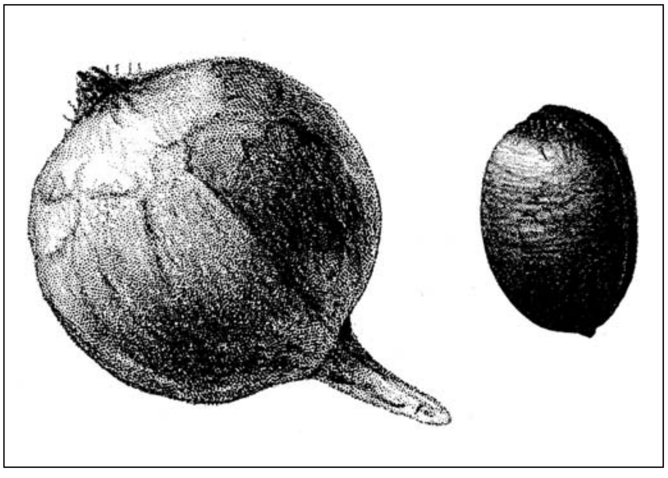
Table 1—*Garrya,* silktassel: occurrence, elevational range, and growth form

Scientific name	Common name	Occurrence	Elevation (m)	Growth form
G. buxifolia **Gray**	**dwarf silktassel**	N California, S Oregon chaparral, associated with pine at higher elevations	60–2,133	Brushy shrub
G. elliptica **Dougl. ex Lindl.**	**wavyleaf silktassel**	Central Oregon to Santa Cruz Island, California; coastal & higher elevations inland	3–840	Shrub (< 6 m)
G. flavescens **S.Wats.**	**ashy silktassel**	Pacific Coast states, SW US, Baja California; canyons, deserts, mtns	450–2,740	Shrub (< 6 m)
G. fremontii **Torr.**	**bearbrush**	S Washington to central California; Sierra Nevada & Cascades	150–2,740	Shrub
G. glaberrima **Wangerin**	—	Scattered locations in mtns of Coahuila, Neuvo Leon, & Tamaulipas; between lowland deserts & highland conifer forests	1,487–2,740	Small tree
G. grisea **Wiggins**	—	Baja California; upper Sonoran & transition communities	1,370-2,423	Shrub (2–4.6 m)
G. laurifolia **Benth**.	**laurel-leaf silktassel**	Central Mexico to Central America; semiarid shrub communities	610–3,566	Tree (< 11 m)
G. longifolia **Rose**	—	S Mexico on volcanic slopes	1,280–2,650	Small tree
G. ovata **Benth.**	**eggleaf silktassel**	Arizona, New Mexico, Texas, N Mexico; mtns above lowland deserts	610–2,560	Clumped shrub (2–4.6 m)
G. salicifolia **Eastwood**	—	S Baja California; sandy loam soils	1,554–1,830	Small tree
G. veatchii **Kellog**	**canyon silktassel**	S California, Baja California; lower mtn chaparral & riparian communities	230–2,600	Shrub
G. wrightii **Torr.**	**Wright silktassel**	Arizona, W Texas, N Mexico; arid Sonoran & transition communities	914–2,133	Shrub

Source: Dahling (1978).

Figure 1—*Garrya fremontii*, bearbrush: berry (**left**) and seed (**right**).



well without pretreatment (Reynolds and Alexander 1974). Because of this variability, seeds of Wright silktassel should also be pretreated before testing or sowing. Recommended pretreatments for these species include stratification at 2 to 5 °C in moist sand, vermiculite, or sphagnum moss for 30 to 120 days (Reynolds and Alexander 1974; Mirov and Kraebel 1937), followed by soaking for 17 hours at room temperature in a 100-ppm solution of gibberellin. However, germination of bearbrush was also improved by stratification in moist sand for 90 days at greenhouse temperatures followed by 90 days at 5 °C (Reynolds and Alexander 1974).

Germination tests. Germination tests have been done on pretreated seeds placed in sand, vermiculite, Kimpak™, and sphagnum moss under light for 30 to 60 days, and at temperatures alternating diurnally from 25 to 13 °C, or from 30 to 20 °C (Reynolds and Alexander 1974). Seeds of Wright silktassel had germination capacities of 47 to 86%.

Figure 2—*Garrya wrightii*, Wright silktassel: berry (**left**) and seed **(right**).

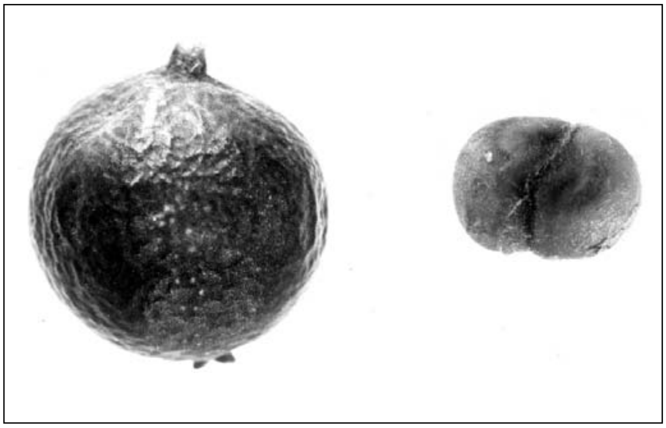
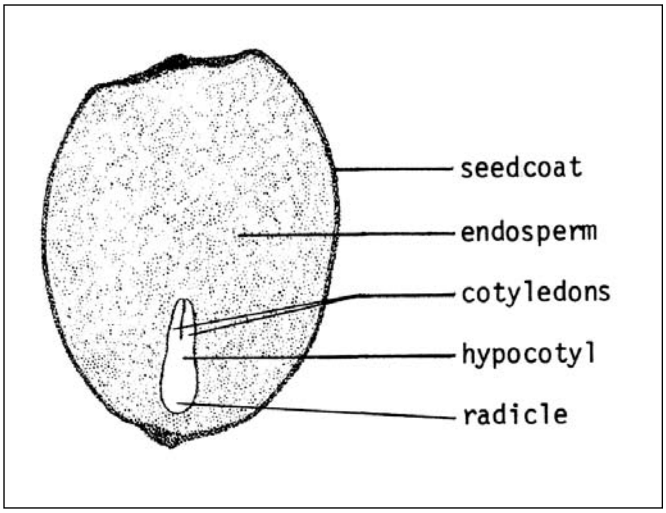


Figure 3—*Garrya fremontii*, bearbrush: longitudinal section through a seed.



Seeds of ashy silktassel germinated best at temperatures between 10 to 15 °C, but poor at 23 to 27 °C. Low-temperature stratification alone does not always result in satisfactory germination of bearbrush (Reynolds and Alexander 1974).

Nursery practice. Seeds of Wright silktassel should be sown in the late winter after 90 days of stratification in moist sand. Sufficient viable seeds should be sown to produce about 100 seedlings/m^2 (9 seedlings/ft^2). They should be covered with about 1.2 cm ($^1/_2$ in) of soil and a light mat mulch. Seedlings are ready for outplanting at age 2 years (Reynolds and Alexander 1974).

Silktassels can also be vegetatively propagated in the nursery. Tip nodal cuttings of wavyleaf silktassel 8 to 18 cm (3 to 4 in) long that were collected in late summer through November, then basally treated with 0.8% indole butyric acid (IBA) and bottom-heated at 20 to 21 °C, successfully rooted within 6 to 8 weeks (Ridgeway 1973). The growth medium should be well drained and only misted during the day. Silktassels are sensitive to root disturbance when actively growing, so dormant potting is recommended (Ridgeway 1973); however, they will not tolerate high fertility in the potting compost. It is difficult to achieve economic rooting percentages unless selection of cutting material, and porosity and hygiene of the rooting medium are carefully controlled (Ridgeway 1985).

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Ericaceae–Heath family

Gaultheria L.

wintergreen

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Growth habit, occurrence, and uses. Of the 100 to 150 species of the genus *Gaultheria*, commonly called wintergreen, most are found in Asia, Australia, and South America. Only 6 species—creeping snowberry, alpine wintergreen (*G. humifusa* (Graham.) Rydb.), *G. miqueliana* Takeda, *G. ovatifolia* A. Gray, checkerberry, and salal—occur in North America north of Mexico (Abrams 1951; Chou 1952; Hitchcock and others 1959; Viereck and Little 1972). The 3 species considered here (table 1) are evergreen shrubs. Both creeping snowberry and checkerberry have a prostrate or creeping form (Fernald 1950) and have been described as semi-herbaceous or almost herbaceous (Fernald 1950; Rosendahl 1955). Salal has a distinctly woody stem and grows 1 to 3 m tall.

Over its wide range in the United States and Canada, creeping snowberry is most common in bogs and wet forested conditions (Curtis 1959; Gleason 1952; MacKinnon and others 1992). Checkerberry tolerates site conditions ranging from dry to poorly drained and grows well on many acidic soil types, including peat, sand, sandy loam, and coal mine spoils (Robinette 1974). Salal also grows on a variety of sites, including shallow rocky soils, sand dunes, glacial till, and peat (Haeussler and Coates 1986). It is most common on well-drained slopes and ridges in coastal Oregon and Washington, on lowland sites in British Columbia, and on low-productivity timber sites in southeast Alaska (Fraser and others 1993; Hemstrom and Logan 1986; Minore and Weatherly 1994; Viereck and Little 1972).

Both creeping snowberry and checkerberry are low cover species valued for wildlife habitat and ornamental use (Dirr 1990; Hitchcock and others 1959; Robinette 1974; Stiles 1980; White and Stiles 1992). Animals known to feed on fruits, buds, or leaves of checkerberry include migratory birds; grouse, including blue (*Dendragapus obscurus*), spruce (*Canachitea canadensis*), and ruffed (*Bonasa umbellus*) grouse; bobwhite quail (*Colinus virginianus*); wild turkey (*Meleagris gallopavo*); ring-necked pheasant (*Phasianus colchicus*); as well as black bear (*Ursus americanus*); white-tailed deer (*Odocoileus virginianus*); and others. Checkerberry is a favorite food of the eastern chipmunk (*Tamias strictus*) (Martin and others 1951; Robinette 1974; Stiles 1980; Van Dersal 1938). Leaves of this species contain oil of wintergreen, which has been extracted for pharmaceutical use, and the edible fruits have been marketed (Dimock and others 1974).

Within the plant communities in which they grow, creeping snowberry and checkerberry occupy a far less

Table 1—*Gaultheria,* wintergreen: nomenclature, and occurrence.

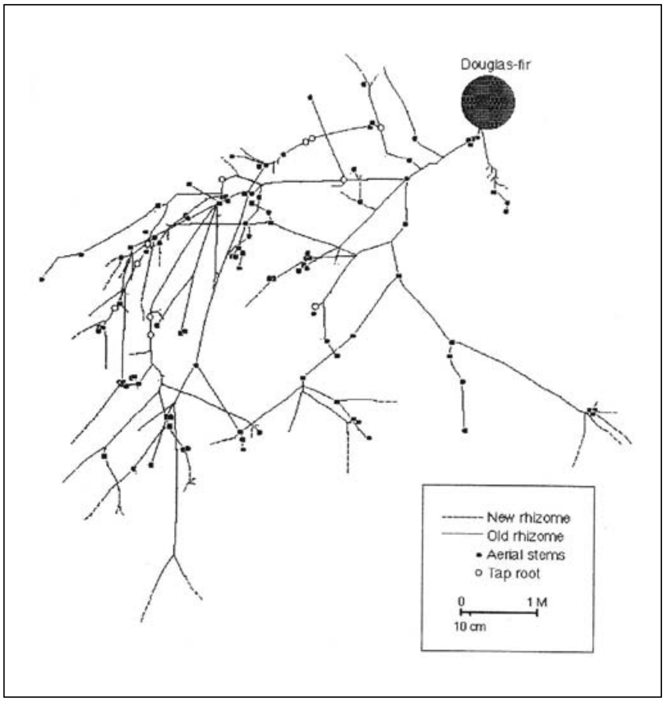
Scientific name & synonym	Common name(s)	Occurrence
***G. hispidula* (L.) Muhl. ex Bigelow** *Chiogenes hispidula* (L.) Torr. & Gray	**creeping snowberry,** creeping pearlberry, moxieplum	Labrador to British Columbia; S to Newfoundland, Nova Scotia & Pennsylvania; higher elevations to North Carolina; W through Michigan, Wisconsin & Minnesota; Idaho
***G. procumbens* L.**	**checkerberry,** wintergreen, mountain-tea	Newfoundland to Manitoba; S through Minnesota & Wisconsin, to Alabama & Georgia
***G. shallon* Pursh**	**salal,** Oregon wintergreen	Pacific Coast from S Alaska to S California inland into the Cascades & Sierra Nevada

Sources: Abrams (1951), Fernald (1950), Gleason (1952), Hitchcock and others (1959).

prominent niche than their Pacific Coast relative—salal. Common to the point of invasiveness, salal is a dominant shrub that lends watershed protection wherever it thrives. Because it rapidly forms dense rhizome mats (figure 1), salal is recommended for sand dune stabilization along the northern Pacific Coast (Brown and Hafenrichter 1962; Huffman and others 1994a&b). Under open canopied forests, salal often forms a dense, vigorous cover that dominates understory plant communities. Sala shoots bearing its glossy, evergreen leaves are highly prized nationwide by the floral industry and marketed as "lemon leaf" in the eastern United States (Sabhasri 1961; Schlosser and others 1991). Harvesters look for dark green sprays, free of discoloration and defect. These are sold as short-stemmed bunches ("tips") or regular bunches 60 to 75 cm long. Salal leaves range from 7 to 21 cm^2 in area, depending on light conditions (Huffman and others 1994b; Messier 1992) and persist on the plant from 2 to 4 years (Haeussler and Coates 1986). A handsome ornamental, salal responds well to cultivation, both domestically and abroad (Fraser and others 1993); wild transplants have been a commercial product (Douglas 1970).

The leaves, buds, and fruits of salal are dietary staples for several game bird species, blue (*Dendragapus obscurus*), ruffed (*Bonasa umbellus*), and spruce (*Falcipennis canadensis*) grouse and band-tailed pigeon (*Patagioenas fasciata*)

Figure 1—*Gaultheria shallon, salal*: diagram of a typical clone comprised of 78 aerial stems and 91 m of interconnected rhizomes growing under an open canopied forest (Huffman and others 1994a).



including (Dimock and others 1974; Martin and others 1951; Van Dersal 1938). Mammals that use its leaves or fruit include black bear, black-tailed deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), Douglas squirrel (*Tamiasciurus douglasi*), Townsend chipmunk (*Tamias* spp.), and mountain beaver (*Aplodontia rufa*) (Hayes and others 1995; Martin 1971; Martin and others 1951; Van Dersal 1938). Salal berries were eaten either fresh or dried by Native Americans; leaves were smoked with bearberry (kinnikinnick)—*Arctostaphylos uva-ursi* (L.) Spreng.—and used in various medicinal preparations (Gunther 1945; Pojar and Mackinnon 1994). The fruit can also be used for jam or preserves (Brown and Hafenrichter 1962; Pojar and Mackinnon 1994).

Flowering and fruiting. The perfect, white to pinkish flowers are borne either solitary and axillary, or in axillary (creeping snowberry) or terminal racemes (figure 2). The number of flowers per inflorescence is 1 to 4 for checkerberry and 5 to 15 for salal (Fraser and others 1993; Reader 1977). Stamens number either 8 (creeping snowberry) or 10 (checkerberry and salal), and ovaries are either 4- or 5-celled, with many ovules (Abrams 1951; Hitchcock and others 1959; Rehder 1940). Flowering dates range from early spring to late summer (table 2). In forest conditions, flowering shoots of salal over 4 years old had greater growth and leaf production than non-flowering shoots the year preceding flowering (Bunnell 1990). Shoot growth and leaf production the same year as flowering was less for flowering shoots than for others. Stems less than 4 years old and those under overstory canopies greater than 33% mean crown cover did not flower (Bunnell 1990). In the nursery, 2nd-year stems produced from rhizome cuttings flowered under light levels as low as 20%, whereas seedlings did not flower

Figure 2—*Gaultheria shallon*, salal: racemes bearing pinkish white flowers.

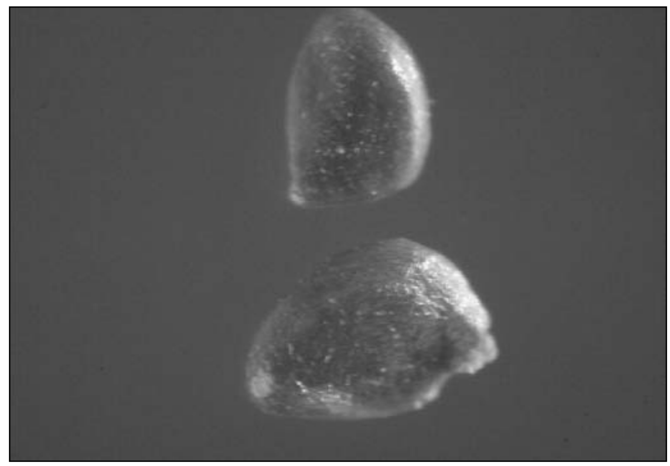
Table 2—*Gaultheria,* wintergreen: phenology of flowering and fruiting

Species	Flowering	Fruit ripening & dispersal
G. hispidula	Apr–Aug	Aug–Oct*
G. procumbens	May–Sept	Aug–June†
G. shallon	Mar–July	July–Dec

Sources: Fernald (1950), Gleason (1952), Hitchcock and others (1959), McMinn (1951), Robinette (1974), Rosendahl (1955), Van Dersal (1938).
* Actual ripening time uncertain.
† Fruit of this species notably persistent and reportedly increase slightly in size during winter (Van Dersal 1938).

Figure 3—*Gaultheria shallon*, salal: the ripe fruit is a purplish black, somewhat-fuzzy pseudo-berry.

Figure 4—*Gaultheria shallon*, salal: the seeds are very small.



under the same conditions (Huffman and others 1994b). Bumble bees are important pollinators of wintergreen (Pojar 1974; Reader 1977). Autogamy also occurs; all 3 species appear self-compatible.

The fruit of wintergreen is a many-seeded capsule surrounded by a persistent, thickened and pulpy calyx that forms a fleshy pseudoberry (Hitchcock and others 1959) (figure 3). The distinctly colored fruits of the 3 species range from 3 to 10 mm in diameter (table 3). Fruits ripen from mid-summer on and are persistent on the plants into winter, thus providing food for birds and mammals, the main dispersers (Stiles 1980; Van Dersal 1938). Checkerberry fruits remain on the plant throughout the winter and are present after snowmelt. Good seedcrops are frequent.

Collection of fruits. Fruits of wintergreen are sufficiently persistent after ripening to permit collection over an extended period (table 2). Depending upon species, they may be combed, stripped, or picked individually from the plant. Refrigeration at temperatures just above freezing minimizes molding if fruits must be stored before processing. Dried fruits of checkerberry vary from 6,250 to 6,600/kg (2,835 to 3,000/lb) (Dimock and others 1974; Swingle 1939) and contain 35 to 81 seeds each (Mirick and Quinn 1981). Dried fruits of salal vary from 8,333 to 1,1494/kg (3,750 to 5,180/lb) (Huffman and others 1994b), averaging 8.5 per cluster (Sabhasri 1961) and containing from 80 to 140 seeds each (Huffman and others 1994b; Zasada 1996). Seeds per fruit averaged 98.7 (range, 79.0 to 125.9) in samples of 20 to 25 fruits collected from widely separated sources (Sabhasri 1961; Zasada 1996). In a nursery study, seed production (seeds per fruit) and fruit dry weight (0.89 to 0.12 g/fruit) were highest for plants growing under 70% light (Huffman and others 1994b).

Extraction and storage of seeds. Either dry or wet seed extraction is possible. Fruits of checkerberry and salal can be dried until they are brittle and powdery, then rubbed through a 30-mesh screen to separate the seeds from the pulp (Dimock and others 1974; Zasada 1996). Seeds of salal can also be separated from dry pulp fragments by using a South Dakota–type seed cleaner (Zasada 1996). Maceration of fresh salal fruits followed by repeated washings to separate seeds and pulp also is effective (Dimock and others 1974). Wintergreen seeds are very small (table 4; figures 4 and 5). Seed weight is a small fraction of fresh fruit weight; for example, 100 lbs of fresh salal fruits produced 2.3 to 4.0 lbs of cleaned seeds (Dimock and others 1972).

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Table 3—*Gaultheria,* wintergreen: growth form, height at maturity, and fruit characteristics

Species	Growth habit	Height at maturity (cm)	Fruit diameter (mm)	Color of ripe fruit
G. hispidula	Prostrate*	20–40*	3–10	Clear–white
G. procumbens	Creeping	5–20	5–10	Scarlet–bright red
G. shallon	Tall shrub	25–300	6–10	Dark purple to bluish black

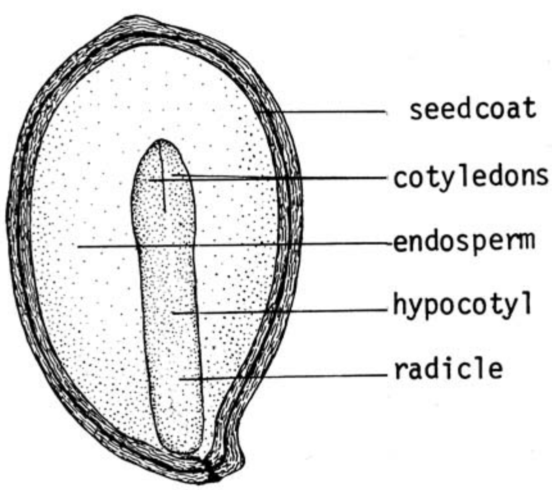
Sources: Fernald (1952), Gleason (1952), Hitchcock and others (1959), Rehder (1940), Rosendahl (1955), Stein (1995).
* Length.

Table 4—*Gaultheria,* wintergreen: seed yield data

	Cleaned seeds (x millions)/weight			
	Range		Average	
Species	/kg	/lb	/kg	/lb
G. hispidula	6.75–6.89	3.06–3.13	6.82	3.09
G. procumbens	6.33–10.67	2.87–4.84	8.50	3.86
G. shallon	5.67–8.33	2.57–3.78	7.14	3.24

Sources: Dimock and others (1974), McKeever (1938), Sabhasri (1961).

Figure 5—*Gaultheria procumbens*, checkerberry: longitudinal section through a seed.



Based on limited evidence, viability of wintergreen seeds may be maintained for 5 years or longer in cool, dry storage; storing seeds at temperatures below freezing has not been studied. Untested seeds of checkerberry stored for 2 years at 5 °C in sealed bottles showed 16% germination (Dimock and others 1974). McKeever (1938) obtained as high as 83% germination of salal seeds stored dry in paper bags at 21 °C for 159 days and 49% for seeds stored at the same conditions for 525 days. Salal seeds declined in germinative capacity from 31 to 21% after 1 year of storage at 4 °C (Sabhasri 1961). Another seedlot showed 73 and 27% germination, respectively, after 3 years of storage at 4 °C or room temperature (Mirov and Kraebel 1937). Some seedlots stored for 3 to 4 years at 1 °C showed 70 to 80% germination and did not differ in germination characteristics from fresh seedlots (Zasada 1996).

Pregermination treatments and germination tests. Very limited data indicate that creeping snowberry and checkerberry require cold stratification to substantially improve seed germination; however, salal does not (table 5). For seeds of creeping snowberry collected in New Hampshire, germination was completed after 98 days in a greenhouse when preceded by winter stratification outdoors for 83 days; unstratified seeds kept in a greenhouse did not germinate (Nichols 1934). Low germination of checkerberry was doubled with stratification (table 5). Salal seeds germinate as well without stratification as with it, but stratification tends to increase the rate and widen the range of temperatures at which germination can occur (table 5). Seeds stratified for 120 days began to germinate in 4 to 12 days at temperatures of 21 to 10 °C, respectively (Zasada 1996). Germination was complete in 18 days at 10 °C; germination was complete in 27 days at 21 °C. Seeds stratified for 150 days began to germinate during stratification. Germination is epigeal (figure 6).

Nursery practice and natural regeneration. Untreated seeds of checkerberry, and perhaps of creeping snowberry, can be sown from fall through early winter, or stratified and sown in the spring (Dimock and others 1974; Rogers 1994). Salal seeds can be sown in the fall or spring without stratification, but stratification will increase germination at lower temperatures.

Surface-sowing is recommended in either glass- or poly-covered flats, in open beds under tacked down loose-weave cheesecloth or muslin (which seedlings penetrate after germination), or under shade cloth (Huffman and others 1994b; McKeever 1938; Rogers 1994). Even without such measures, up to 73% germination has been obtained in soil-filled flats (Mirov and Kraebel 1939). Light for 8 hours/day is recommended. Some propagators expose seeds to an additional 2 hours of light during the dark period (Rogers 1994). A potted plant of checkerberry can be propagated from seeds in 4 months (Rogers 1994). Salal seedlings raised in outdoor nursery beds grew 11 to 17 cm (4.3 to 6.7 in) tall in 2 years (Huffman and others 1994b). They exhibited poor apical dominance, however, developing 6 to 12 aerial stems. Light shade (70% light) produced seedlings with greater biomass, greater canopy size, and more aerial stems compared to those under 20 or 50% or full sun. Under all light intensities, some seedlings produced rhizomes in 2 years.

All 3 species are readily propagated vegetatively from layers, suckers, division of plants, stem or root cuttings, stolons, or rooting at the nodes (Brown and Hafenrichter 1962; Dimock and others 1974; Huffman and others 1994b; Rogers 1994; Sabhasri 1961; Van Dersal 1938). In the Northwest, salal is presently propagated almost entirely by rhizome cuttings (Dimock and others 1974). Cultured rhizome cuttings can produce 5 or more new rhizomes and over 7 aerial shoots/year under light shade during the first 2 years after planting (Huffman and others 1994b). Moist, acid conditions under partial shade are beneficial for young plants of all 3 species raised from either cuttings or seed.

Figure 6—*Gaultheria shallon*, salal: seedling development 2, 8, 15, and 33 days after germination

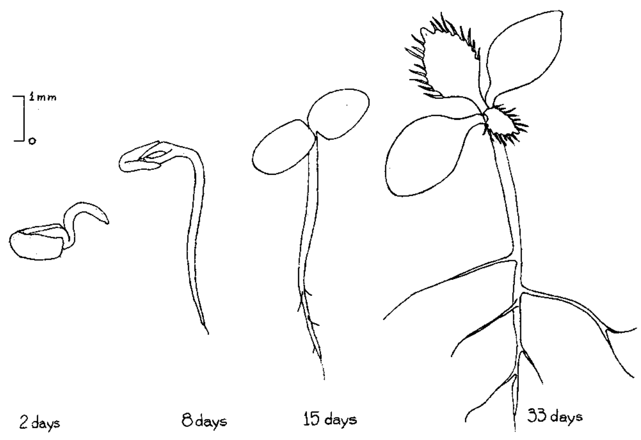


Table 5—*Gaultheria,* wintergreen: stratification, germination test conditions, and results

Species	Cold stratification (days*)	Germination test conditions: Moist medium	Temp (°C): Day	Temp (°C): Night	Germination rate: Days	Germination rate: %	Total germination: Days	Total germination: %
G. hispidula†	83	Soil	—	—	98	—	—	—
G. procumbens	0	Peat	30	20	213	7	59	8
G. shallon	60	Peat	30	20	56	16	15	16
	0	Paper	30	20	61	28	27	38
	30–120	Paper	30	20	55	26	37	31
	0	Sand/soil	21	21	28	74	22	76
	0	Paper/pads	21	16	60	42	30	51
	0‡	Paper/pads	16	10	60	28	30	51
	0‡	Paper/pads	10	4	60	0	30	41
	60‡	Paper/pads	21	16	60	39	30	45
	60‡	Paper/pads	16	10	60	31	30	40
	60‡	Paper/pads	10	4	60	23	30	50
	150‡	Paper/pads	21	16	60	55	30	59
	150‡	Paper/pads	10	4	60	32	30	40

Sources: Dimock and others (1974), Zasada (1996).
* Stratification temperature was 5 °C for *G. procumbens* and 3 °C for *G. shallon.*
† An unknown number of seeds were stratified outdoors during the winter and 147 seeds subsequently germinated in a greenhouse.
‡ Data are for 1 western Oregon seed source; 2 other seed sources had similar responses (Zasada 1996).

Seeds of wintergreen appear to have little innate dormancy under field conditions. No evidence of delayed emergence of salal was observed in 2 replicated studies subsequent to sowing test plots (Huffman and others 1994a; Tappeiner and Zasada 1993). Salal seedlings establish most readily on rotten logs and stumps under partial shade (Huffman and others 1994a; Huffman and Tappeiner 1997). There is evidence that this is also true for checkerberry (Matlack and Good 1989). Forest floor disturbance that exposes mineral soil enhances survival of salal seedlings (Huffman and others 1994a; Tappeiner and Zasada 1993). Predation of seeds did not appear to be a significant factor in a seedling establishment study in the Oregon coastal range (Tappeiner and Zasada 1993). Under field conditions, growth of salal seedlings is slow; they attained average heights of 2 to 4 cm (.8 to 1.6 in) in 2 years but can grow to 20 cm (7.9 in) (Huffman and others 1994a). Seedlings begin vegetative expansion in 4 to 6 years (Huffman and others 1994a). Young seedlings are susceptible to late spring frost (Sabhasri 1961).

Most field regeneration of wntergreen is vegetative (Bunnell 1990; Huffman and others 1994a; Huffman and Tappeiner 1997; Matlack and Good 1990; Matlack and others 1993; Sabhasri 1961). Checkerberry expands by growth of rhizomes and layering of creeping stems where conditions permit (Matlack and others 1993; Robinette 1974). Maximum expansion rates can be 10 cm (3.9 in) per year or more (Sobey and Barkhouse 1977). Clones of creeping snowberry develop as a result of layering of prostrate stems; maximum expansion rates range from 2 to 7 cm (.8 to 2.8 in) per year (Sobey and Barkhouse 1977). Rhizome expansion rates of 44 cm (17 in) per year have been reported for salal; the maximum observed was 93 cm (37 in)/year (Huffman and others 1994a). Individual clones of salal can occupy areas up to 29 m^2 (312 ft^2)with up to 218 m (715 ft) of interconnected rhizomes (figure 1) (Huffman and others 1994a). Salal populations rapidly recover after logging (Halpern 1988; Messier 1992; Messier and Kimmins 1991; Stein 1995) and can severely compete with commercially important tree species (Price and others 1986; Weetman and others 1990; Messier and Kimmins 1990). Clonal assemblages persist by vegetative regeneration of aerial shoots that replace older, dying stems (Huffman and others 1994a). Although shade-tolerant, salal loses vigor with increasing overstory density and clones disintegrate into smaller fragments (Huffman and others 1994a). An estimated minimum light requirement for salal survival ranges from 0.3 to 3.3% of full sunlight (Messier and others 1989).

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Ericaceae—Heath family

Gaylussacia baccata (Wangenh.) K. Koch

black huckleberry

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Synonym. *Gaylussacia resinosa* (Ait.) Torr. & Gray.

Other common names. highbush huckleberry, black-snap, huckleberry.

Growth habit, occurrence, and use. Black huckleberry—*Gaylussacia baccata* (Wangh.) K. Koch—is a small deciduous shrub found from Louisiana east to Florida and north to Maine, Iowa, and Manitoba. It is upright and highly branched and reaches heights of 0.3 to 1.2 m at maturity (Vines 1960). The berries are an important food for wild animals (Van Dersal 1938) and are sometimes eaten by humans. The shrub was cultivated as early as 1772 (Bonner and Halls 1974).

Flowering and fruiting. The small, perfect, pinkish flowers appear in May to June, and the berrylike, drupaceous fruits mature in July to September. They are dark reddish to purple when immature and black when mature. Fruits are 6 to 10 mm long and contain 10 one-seeded, bone-colored nutlets that are 1.5 to 2.0 mm in length (Radford and others 1968; Vines 1960) (figures 1 and 2).

Collection, extraction, and storage. Black huckleberry fruits ("berries") may be stripped from the branches by hand or with blueberry rakes any time after they thoroughly ripen. They often persist for several weeks. Seeds may be extracted by macerating the fruits in water and allowing the pulp and empty seeds to float away. Some samples have been reported to have less than 50% filled seeds. Seed yields of 30 g of cleaned seeds/kg ($^1/_2$ oz/lb) of fruits have been reported (4 samples), with an average of 780 cleaned seeds/g (22,100/oz) (Bonner and Halls 1974). No seed storage studies have been reported with this species, but the seeds appear to be orthodox in storage behavior. This assumption is supported by a report that seeds stored in sealed bottles at 5 °C for over 2 years did not lose viability (Bonner and Halls 1974).

Figure 1—*Gaylussacia baccata*, black huckleberry: exterior view of seed in 2 planes.

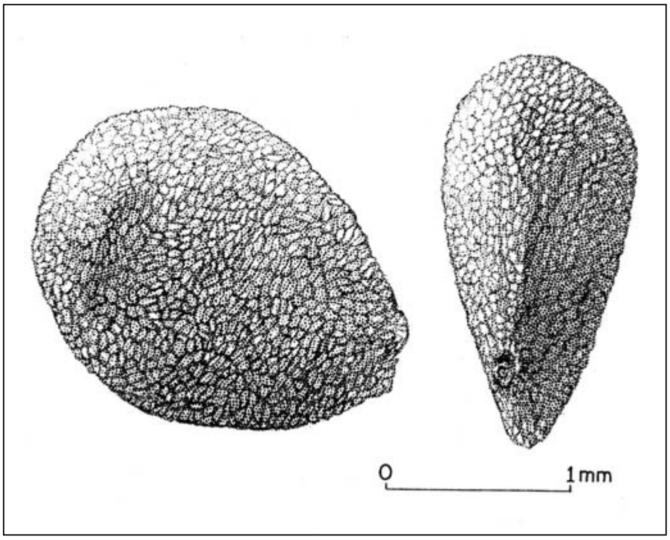
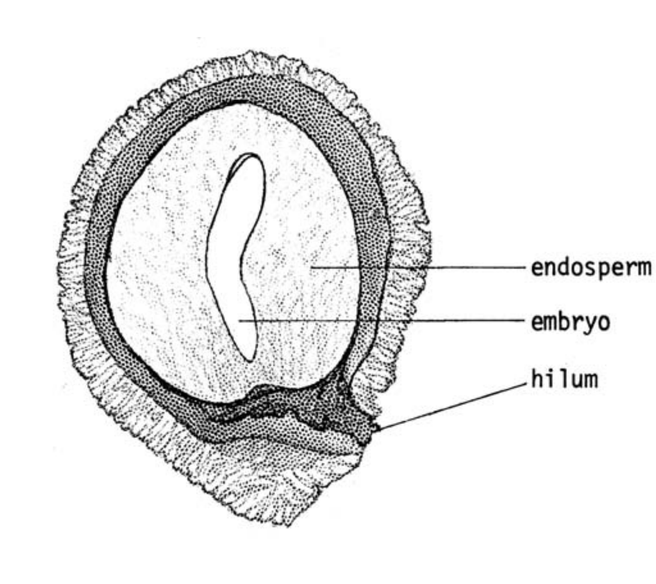
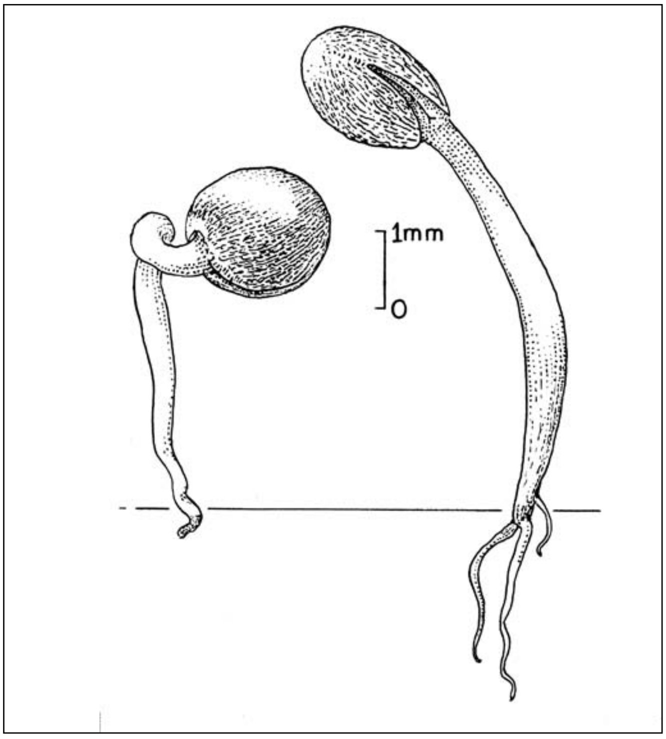


Figure 2—*Gaylussacia baccata*, black huckleberry: longitudinal section through a seed.



Germination. Black huckleberry seeds are dormant and require treatment for good germination. In one test, samples from a 2-year-old seedlot were subjected first to warm stratification in moist peat at diurnally alternating temperatures of 20 to 30 °C for 30 days. Then the temperature was lowered to 10 °C, and 80% of the seeds germinated after 27 days and 96% after 47 days (Bonner and Halls 1974). Germination is epigeal (figure 3).

Figure 3—*Gaylussacia baccata*, black huckleberry: seedling development at 3 and 9 days



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G

Ginkgoaceae—Ginkgo family

Ginkgo biloba L.

ginkgo

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Other common names. maidenhair-tree, Kew-tree.

Growth habit, occurrence, and use. *Ginkgo* is a monotypic genus native to China, the sole survivor of the ancient family of Ginkgoaceae (Bailey 1923; Dallimore and Jackson 1948; Seward and Gowan 1900). Geologic records indicate that ginkgos have grown on Earth for 150 million years (AGINFO 1994). This tall (<35 m) deciduous, sparsely branched, long-lived tree has been cultivated extensively in the Far East and Europe (AGINFO 1994; Bailey 1923, 1947; Seward and Gowan 1900). The foliage of this broad-leaved gymnosperm consists of alternate, simple, fan-shaped, leathery leaves 2 to 5 cm long, with forking parallel veination. Ginkgo trees grow in an upright pyramidal form, becoming broader and regular with age (AGINFO 1994). Ginkgo was introduced into North America in 1784 and has generally been successful on good sites in the moist temperate zone of the midwestern and eastern United States and along the St. Lawrence River in Canada (Bailey 1947; Rehder 1940). Ginkgo trees prefer full sunlight and well-drained conditions and are adaptable to many soils, but they are slow to recover from transplanting (AGINFO 1994). The male of the species is valued as an ornamental and shade tree, particularly as a park and street tree (Bailey 1947). Ginkgo is highly resistant to air pollution and can be grown in areas within its introduced range where air pollution damages other species. The cooked seeds are used for food by the Chinese, but the fleshy layer can cause dermatitis (AGINFO 1994; Porterfield 1940).

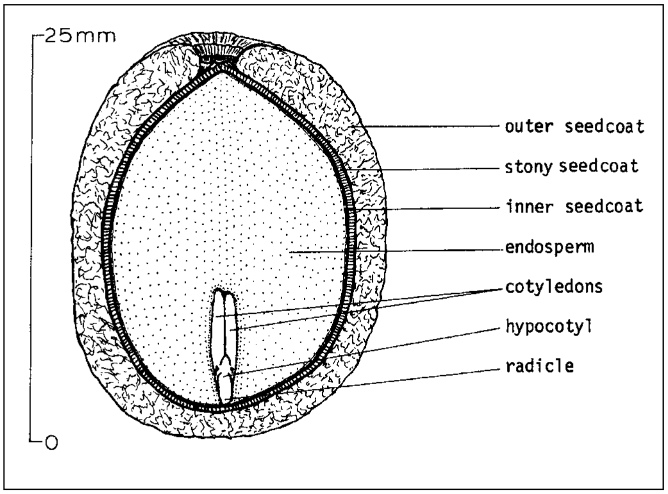
Flowering and fruiting. The species is dioecious. The catkin-like male flowers appear in late March or early April, and the pistillate flowers appear later in April before leafout (Sakisaka 1927). A single naked ovule ripens into a drupe-like seed with a fleshy outer layer smelling of rancid butter and a thin, smooth, cream-colored, horny inner layer (figures 1 and 2). The fleshy coated seeds are frequently called fruits. They are cast in the fall after the first frost, but at this time a larger percentage of the seeds have immature embryos and cannot be germinated under normal test conditions (Alexander 1974; Eames 1955; Willan 1985). Embryo development continues while seeds on the ground are exposed to temperatures normally encountered during fall and early winter. Embryo maturation is usually complete about 6 to 8 weeks after the seeds drop (Lee 1956; Maugini 1965). Because of the offensive odor of the outer layer of the seeds, only male clones are recommended for landscape use (AGINFO 1994).

Ginkgo is also capable of reproducing vegetatively. Del Tredici (1992) describes the origin and development of basal chichi, tuber-like callus growths on the lower trunk that originate from superficial meristematic buds (located in the cotyledonary axils of all ginkgo seedlings) that allow clonal regeneration. Within 6 weeks of germination, these buds become embedded in the cortex of the stem and develop below the bark surface. If a traumatic event damages the tree, these buds grow down from the trunk to form basal

Figure 1—*Ginkgo biloba*, ginkgo: seeds enclosed in their fleshy outer layers (**far left and right**) and cleaned seeds with fleshy layers removed (**center**).

G

Figure 2—*Ginkgo biloba*, ginkgo: longitudinal section through a seed



chichi from which both aerial shoots and adventitious roots can grow. Up to 40% of mature trees Del Tredici observed at 1 location in China were multi-stemmed, with 2 or more secondary stems originating from 1 or more basal chichi. This form of vegetative regeneration may have played a role in the remarkable survival of ginkgo since the Cretaceous Period.

Collection, extraction, and storage. Ginkgo trees begin bearing seeds when they reach 30 to 40 years of age (Hadfield 1960; Ponder and others 1981). The flesh-coated seeds may be collected on the ground as they ripen or picked by hand from standing trees from late fall through early winter. Seeds may be prepared for cleaning by covering them with water for several days until the flesh begins to soften (Munson 1986). Food processing blenders can be used to macerate the softened fruits after their metal blades are replaced with plastic tubing propellers. Fruits should be covered with water, then macerated thoroughly in a blender cup using short bursts of the motor. The pulp is then floated away by slowly adding additional water and allowing filled seeds to sink to the bottom of the cup (Munson 1986). About 12.5 kg (27.5 lb) of cleaned seeds can be obtained from 50 kg (110 lb) of seeds with fleshy layers (Swingle 1939). Cleaned seed density varies from 400 to 1,150 seeds/kg (180 to 520 seeds/lb) (Alexander 1974; Swingle 1939). Cleaned seeds have been kept in ordinary dry storage in both open and closed containers at 5 to 21 °C without any apparent adverse effects (Davis and Henery 1942; Hatano and Kano 1952; Swingle 1939).

Germination. Recommended germination test conditions for ginkgo call for the placement of the seeds, with their coats removed, on the top of or between moist blotters at alternating day/night temperatures of 30 and 20 °C for 30 days (ISTA 1993). Germination tests conducted in moist sand for 60 days using 20 °C nights and 30 °C days ranged from 46% germination for seed collected in October to 90% germination for seed collected in December (Alexander 1974). Germination of untreated seed planted in a soil medium varied from 32 to 85% (Davis and Henery 1942; Swingle 1939). A stratification period of 30 to 60 days at 5 °C before planting has been recommended (Ponder and others 1981), however 1 to 2 months of warm stratification before cold stratification is also advised to allow seeds to fully mature (Dirr and Heuser 1987; Willan 1985).

Nursery practice. Seeds should be sown in the late fall (November), preferably in furrows, and covered with 5 to 8 cm (2 to 3 in) of soil and a sawdust mulch (Alexander 1974; Heit 1967). About half of the viable seeds that are sown will produce usable 2+0 seedlings (Alexander 1974). Ginkgo seedlings grown in artificial growth chambers were able to grow continuously for 20 weeks under a 32 to 25 °C day/night regime (16-hour day-length). This regime produced similar-sized plants as those grown under a 24/17 °C regime for 40 weeks (Flesch and others 1991).

Ginkgo can also be propagated in the nursery from cuttings, although rooted cuttings are slow growing. Cuttings 10 to 15 cm (4 to 6 in) long should be collected from mature trees in midsummer, treated with 8,000 ppm indole-butyric acid (IBA) in solution or in talc, and misted for 7 to 8 weeks (Dirr and Heuser 1987).

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Fabaceae—Pea family

Gleditsia L.

honeylocust

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Growth habit and uses. There are 12 species of *Gleditsia,* but only the 2 North American species and their natural hybrid are considered here (table 1). Honeylocusts are deciduous trees that are useful for windbreaks, shelterbelts, erosion control, wildlife food, and local wood products (posts and railroad ties) (Blair 1990). There are numerous ornamental selections; the most notable is a thornless variety—*G. triacanthos* var. *inermis*—that is widely planted in this country and in Europe (Blair 1990; Dirr and Heuser 1987). Honeylocust has also become highly valued as an agroforestry species in other parts of the world (Davies and Macfarlane 1979; Felker and Bandurski 1979).

Flowering and fruiting. The polygamo-dioecious flowers of honeylocusts are borne in single or densely clustered axillary racemes. Those of waterlocust and honeylocust are greenish in color, whereas flowers of their hybrid are orange-yellow (Vines 1960). Honeylocust fruits are flat, indehiscent, often twisted legumes (pods) 15 to 41 cm in length (Blair 1990) (figure 1). The small, flat, brownish seeds, 8 to 12 mm in length, are embedded in a sweet pulp, the feature that attracts livestock and wildlife to the fruits. Waterlocust legumes are smaller (2.5 to 8 cm), oval-shaped, and pulpless (Vines 1960). Their legumes contain 1 to 3 seeds each, whereas honeylocust legumes may have up to 12. These legume and seed characteristics are the best way to distinguish between the species where both occur together (Brown and Kirkman 1990).

Figure 1—*Gleditsia*, honeylocust: legumes of *G. triacanthos*, honeylocust (**top left**), *G. aquatica*, water honeylocust (**bottom left**), and *G.* × *texana*, Texas honeylocust (**right**).

Table 1—*Gleditsia,* honeylocust: nomenclature, occurrence, height at maturity, and year first cultivated

Scientific name	Common name(s)	Occurrence	Height (m) at maturity	Year first cultivated
G. aquatica **Marsh.**	**waterlocust,** swamp honeylocust.	Coastal plain from South Carolina to Texas,N in Mississippi Valley to Missouri, Illinois, & Indiana	12–18	1723
G. **×** ***texana*** **Sarg.**	**Texas honeylocust,** Texas locust	Mississippi to E Texas, N in Mississippi Valley to Arkansas & SW Indiana	40	1900
G. triacanthos **L.**	**honeylocust,** sweet-locust, thorny-locust	W Pennsylvania to SE South Dakota, S to E Texas & NW Florida; widely planted & naturalized E of Appalachian Mtns from South Carolina to New England	21–43	1700

Sources: Little (1979), Vines (1960).

The seeds are close to the same size (figure 2) and contain a thin, flat embryo surrounded by a layer of horny endosperm (figure 3). Phenology of flowering and fruiting is summarized in table 2. Seedbearing starts at about age 10, with optimum production between 25 and 75 years (Blair 1990). Good crops are borne almost every year (Bonner and others 1974).

Collection of fruits. Fruit color changes from green to a deep reddish brown, or even brownish black at maturity (Brown and Kirkman 1990; Gordon 1966). Legumes may be picked from the trees after they dry or from the ground after natural dissemination, which may last into late winter (Blair 1990). Collection from the ground should be completed early to avoid losses to wildlife and to disintegration of the legumes in late winter or spring. Moist legumes should be spread for thorough drying before extraction. Tree shakers have been used to collect honeylocust fruits in Russia, with as much as 90 to 100% of the crop recovered (Kiktev and others 1977).

Extraction and storage. Dried legumes may be run through macerators or other mechanical threshers to extract the seeds; hand flailing will also work. The Forest Service macerator can extract 180 to 270 kg (400 to 600 lb) of clean seeds per day (Bonner and others 1974). Small trash can be removed with fans, air-screen cleaners, or water flotation, which will also remove empty, insect-damaged, and incompletely developed seeds. Seeds can be separated from large trash, such as legume fragments, with screens.

A seed yield of 44 to 77 kg/100 kg (20 to 35 lb/100 lb) of honeylocust legumes and a purity of 95% and soundness of 98% have been reported (Bonner and others 1974). In 36 seed samples of this species, there was an average of 6,100 seeds/kg (2,800/lb) with a range of 3,800 to 9,000 (1,750 to 4,050). Seeds of Texas honeylocust are generally larger, with 4,000 seeds/kg (1,830/lb) in 1 sample (Bonner and others 1974).

Seeds of honeylocust species are orthodox in storage characteristics. Their viability can probably be maintained for many years if seeds are stored at low temperatures with moisture contents below 10%, although no long-term storage studies have been done. The food reserves in the seeds are primarily carbohydrates and proteins (Felker and Bandurski 1977; Mazzini and Cerezo 1979).

Figure 2—*Gleditsia*, honeylocust: seeds of *G. aquatica*, waterlocust (**top**); *G.* x *texana*, Texas honeylocust (**middle**); *G.triacanthos*, honeylocust (**bottom**).

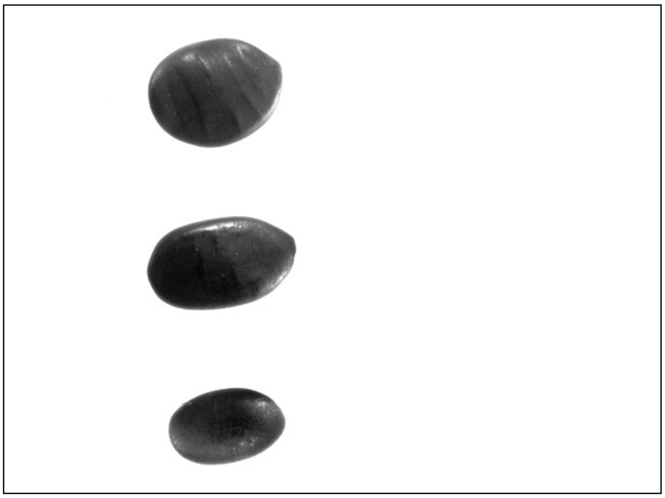
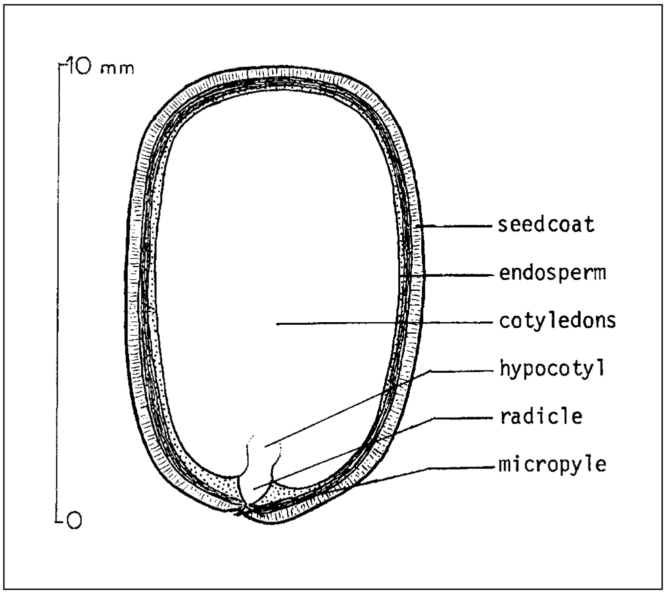


Figure 3—*Gleditsia*, honeylocust: longitudinal section through a seed.



Pregermination treatments. The hard seedcoats of honeylocusts must be treated to make them permeable before germination can occur. Soaking the seeds in either concentrated sulfuric acid or hot water has been used, but

Table 2—*Gleditsia,* honeylocust: phenology of flowering and fruiting

Species	Flowering	Fruit ripening	Seed dispersal
G. aquatica	May–June	Aug–Oct	Sept–Dec
G. × *texana*	Apr–May	Aug–Sept	Sept–Dec
G. triacanthos	May–June	Sept–Oct	Sept–late winter

Source: Bonner and others (1974).

G

the acid treatment has been much more effective. Soaking time in acid must be determined for each seedlot because of variation in seedcoat hardness due to genetic or developmental differences. Several studies have shown that anywhere from 1 to 2 hours is ideal for acid scarification of fully matured honeylocust (Heit 1942; Liu and others 1981). Seeds collected while they are slightly immature will have thinner seedcoats and may be damaged by the acid treatments that work for fully mature seeds. In fact, seeds collected when legumes still show some green areas can often be germinated without any pretreatment. This practice is not recommended, however, because the immature seedcoats are not effective barriers against disease. When the hot water treatment is used, the seeds are placed in 3 to 4 times their volume of water at 85 to 90 °C. Seeds and water are allowed to cool to room temperature or until the seeds swell. The imbibed seeds should be sown promptly, as they will not store well in this imbibed condition.

For pretreatment of small seedlots, as in germination testing, nicking with a knife or burning with a heated needle are both excellent methods (Singh and others 1991). Tests with other legumes (Stubsgard 1986) have indicated that seeds treated with a hot needle can be returned to storage without any problems, and this may be true with honeylocust seeds as well.

Germination tests. Recommendations for official tests call for testing scarified seeds at a constant 20 °C on moist blotter for 21 days (AOSA 1993). Alternating temperatures of 20 and 30 °C also have been used with great success on moist blotters (Singh and others 1991). In 22 tests in other media, pretreated seeds of honeylocust were germinated in a mixture of sand, peat, and soil at 30 °C under light for about 8 hours each day and at 21 °C during the dark period of each 24 hours. Germination ranged from 45 to 99% after 9 and 20 days and averaged 75% in 40 days (Bonner and others 1974).

Nursery practice. Pretreated seeds can be drilled in rows 15 to 25 cm (6 to 10 in) apart and covered with soil to a depth of 12 to 19 mm ($^1/_2$ to $^3/_4$ in). A sowing rate of 33 to 49 seeds/linear m (10 to 15/ft) is recommended (Bonner and others 1974). Mechanical broadcasting of seeds is also feasible. With either method, a desirable seedbed density is 160 to 215 seedlings/m^2 (15 to 20/ft^2) (Williams and Hanks 1976). Seedlings should reach suitable size for field planting in 1 year. Vegetative propagation by hardwood cuttings is extremely difficult, but root cuttings have been quite successful. Budding is also practiced successfully on ornamental varieties (Dirr and Heuser 1987).

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Theaceae—Tea family

Gordonia lasianthus (L.) Ellis

loblolly-bay

Franklin T. Bonner

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Other common names. holly-bay, gordonia, bay, tan bay, black laurel.

Growth habit, occurrence, and use. Loblolly-bay—*Gordonia lasianthus* (L.) Ellis—is a small to medium-sized evergreen tree that occurs on swampy sites on the Atlantic Coastal Plain from Albermarle Sound in North Carolina south to central Florida, with separate populations in southern Alabama and Mississippi (Gresham and Lipscomb 1990; Little 1979). This relatively slow-growing tree can attain a height of 23 m on rich sites but is shrubby on poorer ones. Although its bark was once used locally for tanning leather, loblolly-bay has little commercial value now except as an ornamental (Brown and Kirkman 1990).

Flowering and fruiting. The perfect, showy, white flowers open for 2 to 3 days in May to August; 7 to 8 cm wide, they are borne singly on long stalks in axillary clusters. Pollination is primarily by insects. The fruits are ovoid, woody capsules 12 mm in diameter and 20 mm long (figure 1); they contain from 10 to 40 small, square, winged seeds about 1.5 mm long (figures 2 and 3). The capsules turn brown as they mature in September or October, and most seeds are disseminated by wind by mid-December (Brown and Kirkman 1990; Gresham and Lipscomb 1990; Vines 1960).

Collection, extraction, and storage. Capsules should be collected when they turn brown in the fall. They can be opened with air-drying, and the seeds are then easily extracted by shaking. There are 264,550 to 332,895 dry seeds/kg (120,000 to 151,000/lb) (Gresham and Lipscomb 1990). No storage data are available for this species, but the nature of the seeds suggests that they are orthodox and can be stored easily at low temperatures and low seed moisture contents.

Germination and nursery practices. Loblolly-bay seeds have no dormancy and will germinate readily when sown (Dirr and Heuser 1987). There are no published recommendations for germination testing, but the ease of germination suggests that the common alternating regime of 20/30 °C would suffice. Germination of 70 to 80% within 10 days in petri dishes in sunlight has been reported (Gresham and Lipscomb 1990). Germination is epigeal. This species is also very easy to propagate vegetatively. Cuttings taken in June through August rooted 90 to 100% in peat–perlite and mist with 3,000 ppm of IBA applied (Dirr and Heuser 1987).

Figure 1—*Gordonia lasianthus,* loblolly-bay: capsules.

Figure 2—*Gordonia lasianthus*, loblolly-bay: seeds.

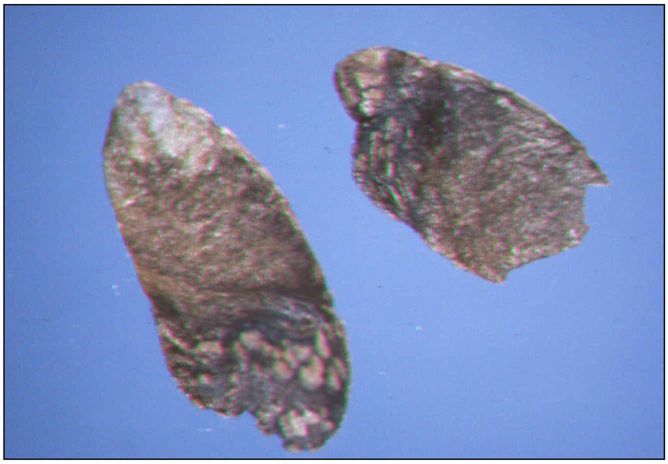
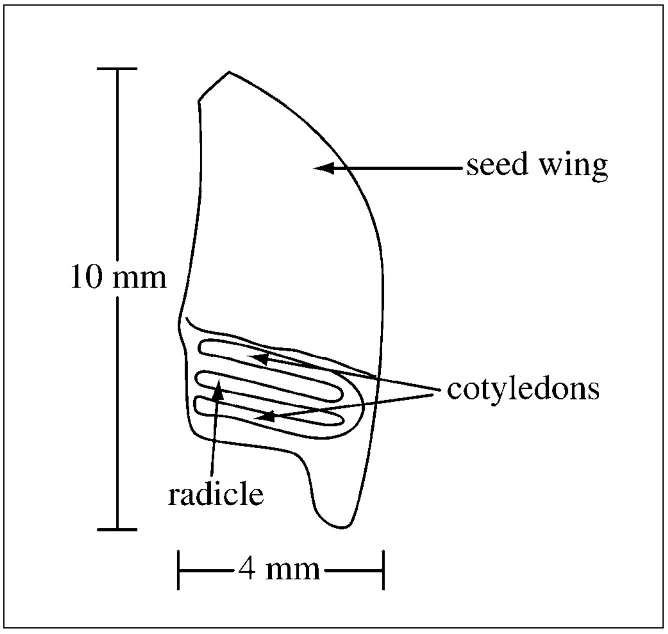


Figure 3—*Gordonia lasianthus*, loblolly-bay: longitudinal section of a seed.



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Chenopodiaceae—Goosefoot family

Grayia spinosa (Hook.) Moq.

spiny hopsage

Nancy L. Shaw, Marshall R. Haferkamp, and Emerenciana G. Hurd

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Growth habit, occurrence, and use. The genus *Grayia* Hook. & Arn., named for the American botanist Asa Gray, contains a single species—spiny hopsage (table 1). Plants are erect to rounded, summer-deciduous shrubs 0.3 to 1.2 (1.5) m tall. Branches are divergent and thorn-tipped, with whitish gray to brownish bark that exfoliates in long strips. Leaves are gray-green, alternate, entire, and fleshy, sometimes turning bright red before abscising. Pubescence of young twigs and leaves consists of simple or stellate hairs. Prominent globose, gray-green overwintering leaf buds develop prior to summer leaf fall.

Widely distributed in the western United States (table 1), spiny hopsage is a common associated species in Wyoming big sagebrush, salt desert shrub, pinyon–juniper, Mojave Desert, and Great Basin–Mojave Desert transition communities, but it rarely grows in monocultures (Welsh and others 1987). The species occurs at elevations ranging from 160 to 2,130 m on soils that are silty to sandy, neutral to strongly basic, and often high in calcium. It also grows on sand dunes. Growth and nutrient content of vegetation growing near spiny hopsage are enhanced by the accumulation of litter rich in potassium and other cations (Rickard and Keough 1968).

Spiny hopsage provides cover for birds and other small animals; spring and early summer forage for big game and livestock, and soil stabilization on gentle to moderate slopes (McCullough 1969; USDA SCS 1968). The species was first cultivated in 1897 (Rehder 1940).

Geographic races and hybrids. Spiny hopsage is tetraploid (4x = 36) (McArthur and Sanderson 1984). Natural hybridization between spiny hopsage and related members of the Chenopodiaceae has not been observed. However, Drobnick and Plummer (1966) were successful in fertilizing female flowers of fourwing saltbush—*Atriplex canescens* (Pursh) Nutt.—with spiny hopsage pollen and obtaining viable progeny.

Flowering and fruiting. Plants are monoecious or dioecious, with the percentage of each varying among populations (Goodrich and Neese 1986; McArthur and Sanderson 1984). Inflorescences develop on floral shoots that die back following fruit dispersal. Flowers are inconspicuous. Staminate flowers, each consisting of a 4- or 5-lobed perianth and 4 or 5 stamens, develop in glomerate spikes. Pistillate flowers develop in dense bracteate spikes, racemes, or panicles with 1 to several flowers in the axil of each bract. Some flowers are commonly vestigial. Each flower

Table 1—*Grayia spinosa*, spiny hopsage: nomenclature and occurrence

Scientific name & synonym(s)	Common name(s)	Occurrence
G. spinosa **(Hook.) Moq.** *Chenopodium spinosum* Hook. *G. polygaloides* Hook. & Arn. *Eremosemium spinosum* Greene *Atriplex grayii* Collotzi *A. spinosa* (Hook.) Collotzi	**spiny hopsage**, applebush, grayia, Gray's saltbush, hopsage, horsebush, saltbrush, spiny-sage, wintersage	E-central & SE Washington, E Oregon, S & central Idaho, S Montana, Nevada, Utah, W Wyoming W Colorado, E & S California, & N Arizona

Sources: Collotzi (1966), Dayton (1931), Hitchcock and Cronquist (1973), Kay (1977), Shaw (1992a&b), Smith (1974), Welsh and others (1987).

consists of a single pistil enclosed in 2 cordate to orbicular bracteoles united along their length except for a minute apical opening. Bracteoles enlarge in fruit, forming a papery, dorsally wing–margined sac 9 to 15 mm in diameter (Shaw and others 1996) (figure 1). Mature bracteoles are white, green, or parchment-colored and are sometimes suffused with pink or red.

Fruits are utricles with the thin, papery pericarp free from the seed (Shaw and others 1996) (figure 2). Seeds are vertical, disk-shaped, and 1 to 2 mm in diameter (figure 3). The seedcoat consists of a thin, dark brown outer layer and a tough, elastic inner layer. A well-developed embryo with pale yellow cotyledons and an elongate, inferior radicle encircles the perisperm (figure 4).

During a prolonged drought, spiny hopsage shrubs developing from a southern Idaho seeding began flowering in the 4th year (Shaw 1992b). Flowering occurs in late winter or early spring (table 2) and may be triggered by photoperiod (Ackerman and Bamberg 1974). Flowers are wind-pollinated. Fruits mature in late spring or early summer and are usually dispersed within 1 or 2 weeks. High winds accompanying summer storms can rapidy remove all mature fruits. Herbage, flower, and fruit production are dependent upon the availability of soil water and other environmental factors and vary widely among years (Rickard and Warren 1981; Wallace and Romney 1972). In dry years, plants may remain dormant, producing neither leaves nor flowers.

Figure 1—*Grayia spinosa*, spiny hopsage: bracted utricle

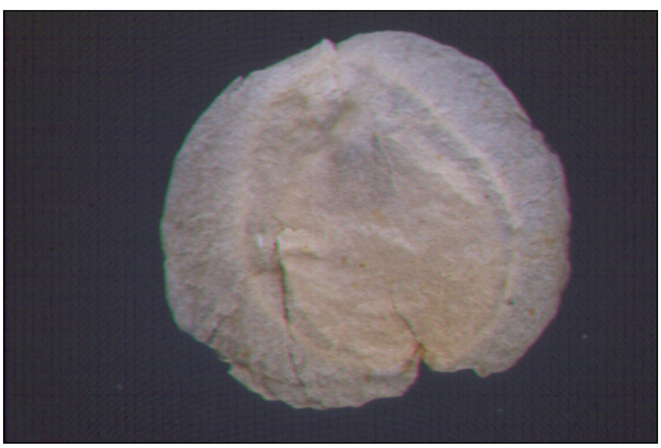


Figure 2—*Grayia spinosa*, spiny hopsage: utricle.

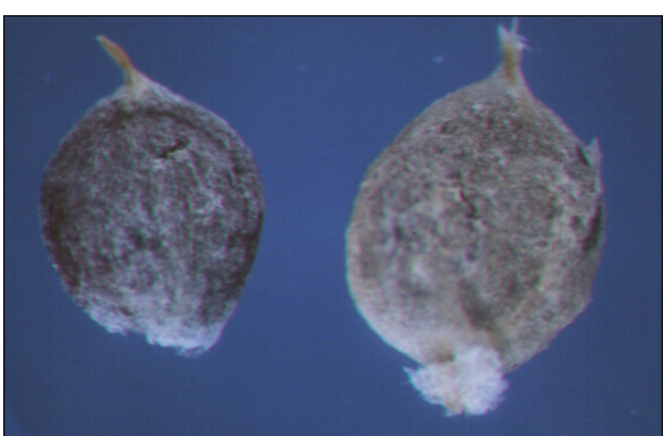


Figure 3—*Grayia spinosa*, spiny hopsage: seeds.

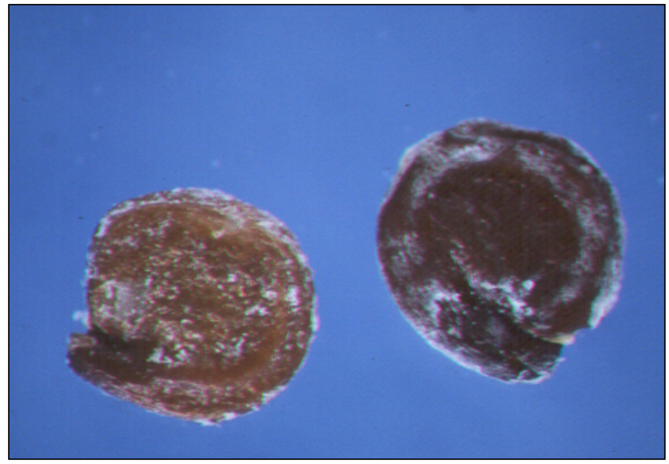
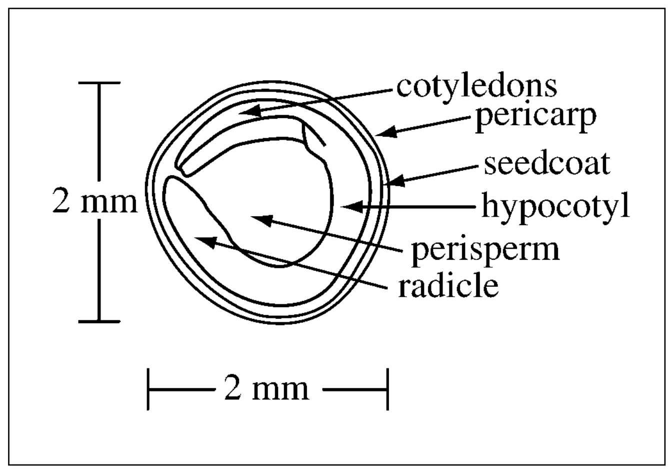


Figure 4—*Grayia spinosa*, spiny hopsage: longitudinal section through a seed.



Collection of fruits. Size and quality of the developing seed crop at prospective collecting sites should be estimated prior to the harvest season. Mature utricles can be harvested by hand-stripping or by beating the shrubs with paddles or tennis rackets. Freshly harvested utricles should be spread in a thin layer over drying racks or screens in an enclosed area with good ventilation. Utricles dried outdoors or in open buildings must be covered with netting or wire screens as they are easily scattered by light breezes. The hygroscopic bracts absorb water rapidly if exposed to environments with increased humidity.

Seed extraction and cleaning. Preliminary separation of harvested seedlots with an air-screen machine removes twigs, large leaves, and other coarse material. Some empty bracts can also be separated by this process. Bracteoles may be removed, if necessary, by threshing them with a hammermill (King 1947) or a barley de-bearder (Jorgensen 1992). A seed scarifier, seed de-winger, or rubbing board may be used to thresh small collections (Shaw and Haferkamp 1990). Threshing generally results in complete removal of bracteoles and partial to complete removal of the pericarp, leaving seeds as the product. Some embryos may be damaged during threshing as the radicle tip is vulnerable to abrasion (figure 4).

Threshed seeds may be separated from chaff using an air-screen machine or a seed blower. Removing the chaff is necessary only when it is desirable to reduce bulk for storage or shipping. Otherwise, the chaff can serve as a diluent for the small seeds as it will feed through most seeding mechanisms when dry. Smith (1974) obtained 1.2 kg (2.6 lb) of cleaned seeds from 45.4 kg (100 lb) of fruits. Number of bracted utricles and seeds per weight and seed fill data are provided in table 3.

Storage. Kay (1976) and Kay and others (1977, 1984, 1988) found that total germination percentage of seeds dried to a water content of 5.1% and stored at –15 or 4 °C or room temperature in sealed glass containers containing a silica gel desiccant did not decline from the initial value of 42% after 14 years (Kay 1976; Kay and others 1977, 1984, 1988). Germination of air-dried seeds stored in cloth bags in a warehouse decreased to about 20% after 1.5 years and to 0% after 7 years. All germination tests were conducted at 15 °C. Thus, for long-term storage, it is recommended that seeds be dried to a water content below 10% and kept in sealed containers.

Pre-germination treatments and germination tests. Dormancy of freshly harvested utricles of many woody chenopods can be reduced by dry after-ripening, whereas the response to wet prechilling and temperature is regulated by the environmental conditions in which they were produced (Ansley and Abernethy 1985; Kay and others 1988; Springfield 1972). However, the response of spiny hopsage seeds to dry after-ripening is poorly known and may vary with seedlot and with seed age. Shaw and others (1994) found that field germination and seedling establishment of 2 spiny hopsage seed collections from the northern shrub steppe were similar after 2 and 4 years of dry storage at room temperature. By contrast, King (1947) found that an additional 2 years of dry after-ripening decreased the wet prechilling (5 °C) requirement for eastern Washington seeds from 12 weeks for 4-year-old seeds to 2 weeks for 6-year-old seeds.

Spiny hopsage seeds produced in the northern shrub steppe generally have a requirement for wet prechilling; seeds produced in the Mojave Desert do not (Shaw 1992a;

Table 2—*Grayia spinosa*, spiny hopsage: phenology of flowering and fruiting

Location	Flowering	Fruit ripening	Seed dispersal
Northern Mojave Desert, Nevada	Mar	Mar	Mar
Great Basin, Mojave Transition Desert, Nevada	Feb–April	Mar–Apr	Apr
Book Cliffs, Colorado	Mar–May	May	May–June
Great Basin, Nevada	April & June	May & July	May & Aug
Sagebrush steppe, Oregon & Idaho	April–May	May–June	May–June

Sources: Ackerman and Bamberg (1974), Ackerman and others (1980), Blauer and others (1976), Branson and others (1967), Everett and others (1980), Goodrich and Neese (1986), Plummer and others (1968), Shaw (1992b), Wallace and Romney (1972).

Table 3— *Grayia spinosa*, spiny hopsage: fruit and seed numbers per weight

Bracted utricles/weight		Seeds/weight: Range		Seeds/weight: Average	
/kg	/lb	/kg	/lb	/kg	/lb
337,000–447,000	152,900–202,800	339,000–930,000	153,800–421,800	500,000	227,000
—	—	692,600–1,031,600	314,200–468,000	1,219,500	553,200

Sources: Belcher (1985), Kay and others (1977), King (1947), Plummer and others (1968), Shaw (1992b), Smith (1974), Swingle (1939).
Note: Filled seeds (%) = 18 to 95.

Wallace and Romney 1972; Wood and others 1976). Shaw (1992a) examined the effect of 45 days of wet prechilling at 3 to 5 °C on 2 northern shrub steppe collections. Prechilled bracted utricles and cleaned seeds of each collection were incubated over a wide range of constant (10, 15, 20, 25 or 30 °C) and alternating (8/16 hours) temperatures (15/5 °C and 10/2 °C). Prechilling increased germination from 9 to 64% and reduced days required to reach 50% germination from 40 to 29. Based on these results, she recommended 1 to 2 months of wet prechilling for northern shrub steppe seedlots.

Wood and others (1976) examined the germination response of 4 Nevada (Great Basin) and 1 California (Mojave Desert) spiny hopsage seedlots at 5 constant and alternating temperatures. Prechilling was not required as the seeds were nondormant. After 1 week, germination of seedlots incubated at constant temperatures was greatest at 10 and 15 °C (66 to 74%). For a seedlot collected at Dayton, Nevada, a 5 °C low temperature alternating with high temperatures between 10 and 30 °C, inclusive (8/16 hours alternations), provided the greatest germination percentages (85 to 90%). Maximum seedling elongation for this seedlot occurred after 1 week at 5, 20/15, 20, or 25/5 °C.

Wood and others (1976) also found that the presence of bracts did not affect germination of seeds collected in Nevada and California that were exposed to favorable incubation conditions. At low water potentials, greater germination of bracted utricles compared to seeds was attributed to the presence of the hygroscopic bracteoles. Shaw (1992a) found that prechilling enhanced subsequent germination of seeds more than bracted utricles from northern shrub steppe populations when placed under favorable incubation conditions and speculated that enhancement might be due to improved oxygen uptake by the seeds.

The following techniques and criteria (with instructions) are recommended for laboratory analyses by Belcher (1985), Dueleheimer (1992), and Shaw (1992a):

Germination—Incubate seeds at 15/5 °C (8 hours/16 hours) or 15 °C. First count is taken at 7 days, last count at 14 days. Wet prechilling for 30 to 60 days at 3 to 5 °C is recommended for northern populations. Normal seedlings are epigeal, with a thin, 10- to 15-mm-long hypocotyl; small, narrow cotyledons; short epicotyl; and well-developed roots hairs (figure 5).

Embryo excision—Soak seeds in water at 28 °C for 12 hours, then drain; excise embryos with sharp needles. Spiny hopsage embryos germinate rapidly at 15/5 or 15 °C. Evaluate as described for germination of seeds.

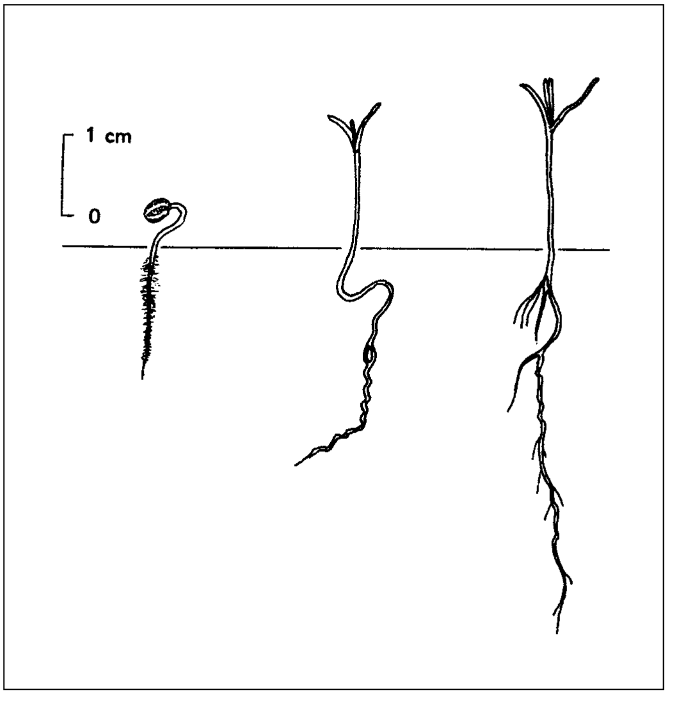
Viability testing—Soak seeds in water at 28 °C for 12 hours, then drain; pierce seeds through perisperm with a sharp probe or needle; soak in a 1% 2,3,5-triphenyl tetrazolium chloride solution for 4 to 8 hours at 28 °C. Excise embryos with sharp needles and evaluate as described by Peters (2000) for members of the Chenopodiaceae.

X-radiography—Shoot at 12 kV for 30 seconds with Kodak® AA film and Industrex® paper or at 12 kV for 60 seconds with Polaroid® film. Filled, empty, and abnormal development will be visible.

Nursery practice. Container stock can be grown using planting media as described by Augustine and others (1979), Ferguson (1980), and Ferguson and Monsen (1974). Seeds should be wet prechilled, if necessary.

Bareroot stock of northern spiny hopsage populations may be produced by fall-seeding to permit early spring germination (Shaw 1992a, Shaw and Haferkamp 1990). This treatment maximizes the period of active seedling growth prior to leaf abscission and the onset of summer dormancy. Spring seedings of prechilled seeds generally have not been successful as it is difficult to prepare and plant the nursery beds early enough in the season. Seedlings developing from fall plantings generally produce a branched shoot and a taproot system with few lateral roots during the first growing season. Plants may attain adequate size for lifting as 1+0 stock, or they may be allowed to grow for an additional sea-

Figure 5—*Grayia spinosa*, spiny hopsage: seedling development at 1, 9, and 14 days after germination.



son, during which time they develop a more extensively branched root system. Bareroot seedlings must be lifted, packed, and handled with care as stems and branches are brittle and break easily. For prolonged storage, seedlings should be stored at –2 °C in paper nursery bags packed in waxed cardboard boxes to reduce desiccation and mold problems (Beall 2000).

Dormant bareroot spiny hopsage seedlings or container stock should be planted as soon as the ground thaws and before native shrubs in the vicinity of the planting site break dormancy. Removal of competing vegetation is critical to survival of the shrub seedlings. Container stock has been established using supplemental water the first year (Ferguson and Frischknecht 1981, 1985; Frischknecht and Ferguson 1984; Hunter and others 1980; Romney and others 1971; Tueller and others 1974; Wallace and Romney 1974; Wallace and others 1980). Hunter and others (1980) recommended protecting seedlings with chicken-wire sleeves to reduce seedling predation in areas with high rodent or rabbit densities.

Direct seeding. In the commercial trade, "cleaned seeds" may mean bracted utricles from which coarse debris has been removed or seeds that have been separated from the bracteoles, pericarp, and extraneous debris. Either bracted utricles or seeds may be planted, but it is important to know which structure one is using. Bulk is considerably greater for bracted utricles, whereas purity and viability are generally greater for seeds. When bracted utricles ("fluffy" seeds) are being planted, a conventional drill seeder with an agitator or a drill with a separate seed box and agitator are needed to ensure uniformity of flow. Seeds may be planted with most conventional seeders. Regulating the seeding rate for the small seeds may be difficult unless they are sown through a drill with precision seeding regulation or mixed with either a diluent or seeds of other shrubs.

Broadcasting without covering the seeds is not recommended. However, seeds or bracted utricles can be broadcast-seeded if they are incorporated into the soil by harrowing. Wood and others (1976) found emergence from broadcast seeding on a rough seedbed was greater from bracted utricles (18%) than from seeds (0%) in a greenhouse study. However, emergence of both bracted utricles and seeds was greater and similar (50%) from a 5-mm planting depth.

Spiny hopsage has been planted in southern Idaho in late fall or winter by direct seeding or by broadcasting and covering. Seeds are thereby exposed to cool, wet seedbed environments, permitting early spring emergence when soil water conditions are favorable for growth prior to the onset of summer drought (Shaw and others 1994). Some seeds not encountering favorable soil water conditions for germination may enter secondary dormancy. Shaw and Haferkamp (1990) found seedling density was greater on rough seedbeds than on smooth seedbeds in early spring, perhaps because of improved microsite conditions. First-year establishment ranged from 0 to 24% of viable seeds planted from early fall to late spring on rough and smooth seedbeds. Seedling predators included seed harvester ants (*Pogonomyrmex salinus* Olsen) and nymphs of an unidentified plant bug (*Melanotrichus* spp.).

Microenvironmental conditions in prepared seedbeds differ sharply from those in natural seedbeds as spiny hopsage seedlings usually establish beneath nurse plants (Manning and Groeneveld 1990; Shaw and Haferkamp 1990). Consequently, spiny hopsage establishment may be enhanced by mulching or water catchment techniques that moderate soil water and temperature conditions.

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Proteaceae—Protea family

Grevillea robusta A. Cunningham ex R. Br.

silk-oak

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Synonym. *Stylurus robusta* (A. Cunn.) Deg.

Other common names. silver-oak, lacewood.

Growth habit, occurrence, and use. Silk-oak—*Grevillea robusta* A. Cunningham ex R. Br.—is a medium to large evergreen tree native to coastal regions of eastern Australia (Skolmen 1990). Silk-oak is commonly planted as an ornamental for its showy orange blossoms, and in reforestation programs in many warm–temperate, subtropical, and tropical locales worldwide. In the United States, it has been planted in Hawaii (since about 1880), California, Florida, and Puerto Rico, and has become naturalized in Hawaii and southern Florida, where it is considered by some to be a noxious weed (Skolmen 1990). The species has adapted well to Hawaii's varied climates and grows vigorously from sea level to 1,200 m (Neal 1965). Its prolific seeding, wide dissemination of the seeds by wind, and its tolerance of diverse site conditions have enhanced its ability to proliferate (Wong 1974). The tree attains heights of up to 35 m and diameters up to 0.9 m (Wong 1974).

The pale pinkish brown wood has a beautiful, well-marked silver grain, making it desirable for furniture and cabinet work (Magini and Tulstrup 1955; Skolmen 1990). However, care must be taken when machining and finishing this wood because the sawdust contains a skin irritant that produces an uncomfortable rash lasting a week or more. Hydrocyanic acid has been detected in the fruit and flowers (Wong 1974).

Another species—Kahili flower, *Grevillea banksii* R. Br.—is less common because reforestation attempts with it have failed in Hawaii. Only on Kauai and Maui are remnant stands of early plantings found (Wong 1974). It is a smaller tree, up to 10 m in height. The flowers and fruits of this species also contain cyanogenic compounds that produce a rash similar to that from poison-ivy (*Toxicodendron radicans* ssp. *radicans* (L.)) Kuntze; see *Rhus* (p.954) (Magini and Tulstrup 1955; Wong 1974). A white-flowered form of this species—white Kahili flower, *G. banksii* forma *albiflora*—is also found in Hawaii (Wong 1974) and is officially classified there as a noxious weed (Haselwood and Motter 1966).

Flowering and fruiting. Silk-oak is monoecious and flowers from early March through October, reaching its peak during the months of April through June in Hawaii (Little and Skolmen 1989; Skolmen 1990; Wong 1974). Trees in Hawaii usually begin producing flowers and seeds when they are 10 to 15 years old (Wong 1974). In Jamaica, trees seed profusely from 10 years of age (Streets 1962). The bright orange blossoms are borne on horizontal racemes, 8 to 18 cm long, which are on short, leafless branches arising mostly from the trunk (Little and Skolmen 1989). The fruit, which turns from green to black on maturity, is a slightly flattened, leathery, dehiscent follicle, 15 to 25 mm long, tipped with a slender, recurved, stiff style (figure 1) (Little and Skolmen 1989; Wong 1974). The follicles remain on the tree for a year or so after the seeds are dispersed (Neal 1965). Two brown, elliptical, flattened seeds—each 10 to 15 mm long with light, winged margins—are found in each follicle (figures 1 and 2). Seedcrops of Kahili flower resemble those of silk-oak. The blossoms of silk-oak are orange, those of Kahili flower are red, and those of white Kahili flower are creamy white.

Collection, extraction, and storage. The fruits of silk-oak are gathered from the tree before opening, when the first hint of brown color appears, indicating that the seeds are mature (Wong 1974). The seeds are extracted by air-drying the fruits in trays under shade for 5 or 6 days or until the follicles open and release the seeds. The seeds are then separated by means of a seed cleaner (Wong 1974). Purity has averaged 87% (Goor and Barney 1968; Magini and Tulstrup 1955). Moisture content of fresh seeds collected in Hawaii was 28.5% (ETSL 1969). The following numbers of seeds per weight have been reported for 3 locations: Hawaii, 64,700/kg (29,350 lb) (ETSL 1969); East Africa, 66,000 to 154,000/kg (29,950 to 69,850/lb) (Parry 1956); and Australia, 79,200 to 99,000/kg (35,925 to 44,900/lb) (Goor

Figure 1—*Grevillea robusta*, silk-oak: follicle and seed.

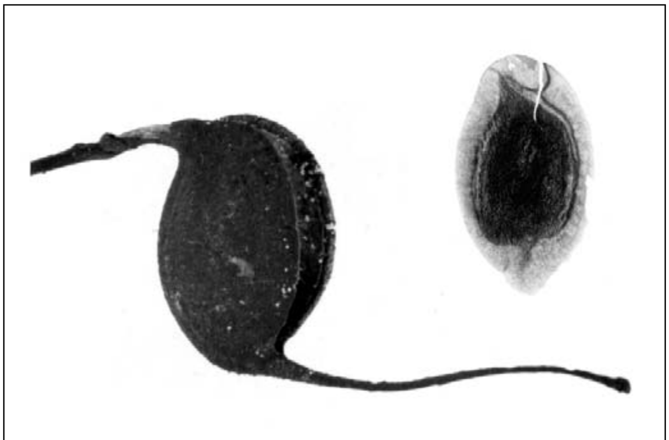
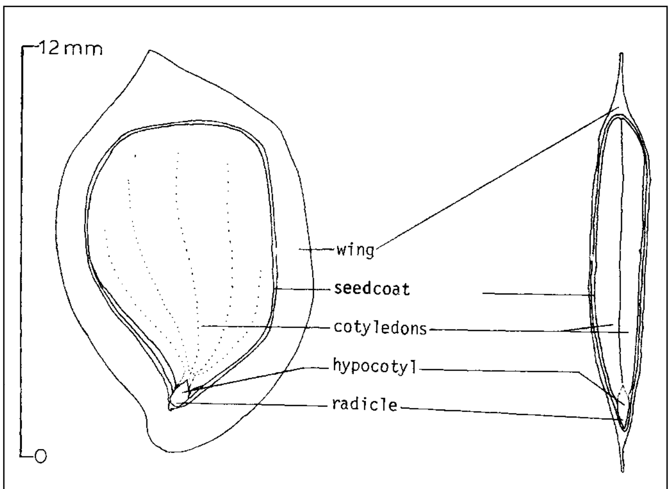


Figure 2—*Grevillea robusta*, silk-oak: longitudinal section through a seed.



and Barney 1968). Seeds of silk-oak are orthodox in storage behavior and are easy to store in cool, dry conditions (Schaefer 1991). Seeds stored for 2 years at –7 and 3 °C had germination rates ranging from 60 to 70% when seed moisture was maintained below 10% during storage in airtight containers (Jones 1967).

Germination. Testing procedures for official purposes call for 21 days of testing at alternating temperatures of 20/30 °C with no pretreatment (AOSA 1993). Two pregermination treatments have been found to increase substantially the germination of stored seeds (ETSL 1969). A 48-hour water soak and stratification at 3 °C for 30 days were equally effective. Pretreated seeds were germinated on moist Kimpak at diurnally alternating temperatures of 30 °C during an 8-hour light period and 20 °C during the dark period. The average germination rate of 8 samples was 38% after 17 days and 70% after 72 days. Germination of stored, untreated seeds, however, was only 26% (ETSL 1969). Fresh seed in Australia had a germination rate of 60 to 80% (Goor and Barney 1968). Germination of fresh, unstratified seeds require about 20 days (Skolmen 1990). Germination in silk-oak is epigeal.

Nursery practice. Nursery practices vary among countries where silk-oak is grown (Skolmen 1990). In some countries 4- to 6-week-old wildlings are lifted and potted and later replanted. Seedlings grown in Sri Lanka are outplanted when they are about 40 cm (16 in) tall, whereas those in Jamaica are outplanted when about 60 cm (24 in) tall (Streets 1962). Elsewhere, plants are grown to 45-cm (18 in) heights in large baskets so that they can compete more effectively when outplanted. In Hawaii, silk-oak seeds are sown at a depth of 1.25/cm ($^1/_2$ in) without mulch (Wong 1974). Seedbeds are treated with insecticides and fungicides before sowing. Seedling density ranges from 200 to 300 seedlings/m^2 (19 to 28/ft^2). Seedlings grown in flats are outplanted when they are about 9 months old (Wong 1974), whereas container-grown seedlings reach a plantable size of 20 cm (8 in) in height in 12 to 14 weeks (Skolmen 1990).

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Asteraceae—Aster family

Gutierrezia Lag.

snakeweed

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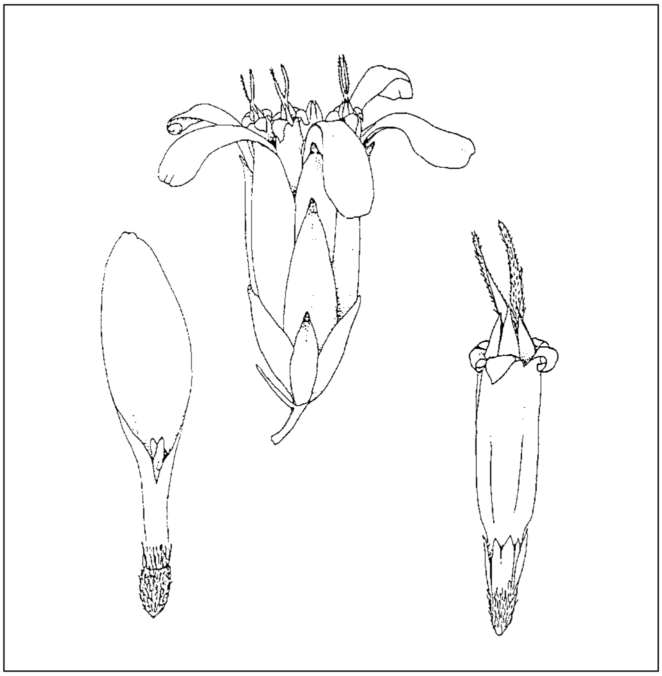
Growth habit, occurrence, and use. The genus *Gutierrezia*—commonly called snakeweed or broomweed—includes 16 annual or perennial species of low-growing woody and herbaceous plants native to the arid regions of North and South America. Shinners (1950, 1951) placed *Gutierrezia* in the genus *Xanthocephalum,* based mainly on morphological characteristics. Since that time, the generic alignment has vacillated between the 2 genera, and publications using either name can be found between 1950 and 1985. Lane (1985) authoritatively resolved the issue when she provided evidence that the name *Gutierrezia* was taxonomically more appropriate. The genus in general—and broom snakeweed (*G. sarothrae* (Pursh) Britt. & Rusby) in particular—is regarded as undesirable on grazing land in the western United States because it interferes with forage growth and is toxic to livestock (McDaniel and others 1982).

Threadleaf snakeweed—*G. microcephala* (DC.) Gray—is closely allied to broom snakeweed and collectively these 2 species are commonly referred to as perennial snakeweed or simply, snakeweed. Other common names often used to describe these species include turpentine weed, rubberweed, rockweed, stinkweed, yellowtop, matchweed, and perennial broomweed. Snakeweeds are widespread on rangeland in the southwestern United States and are rarely included in seeding mixtures.

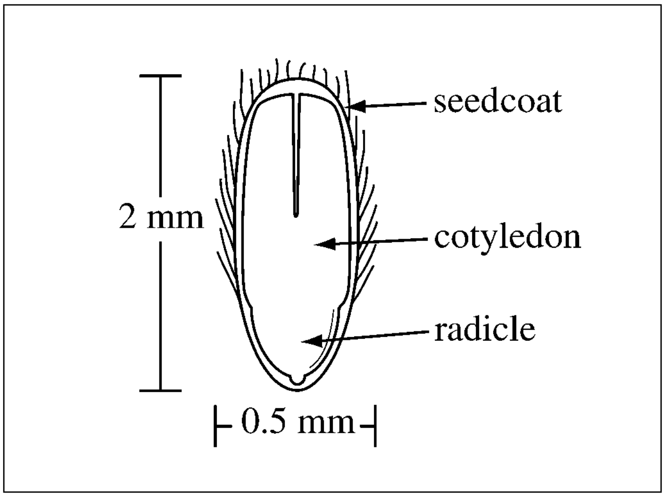
Flowering and fruiting. Flowering heads of broom snakeweed are numerous and small (about 3.75 mm high and 1.75 mm wide) and are borne in clusters of 2 or 3 in panicles or short spikes (Lane 1985; Ruffin 1974; Solbrig 1960, 1964). The heads usually contain 2 to 7 ray flowers with yellow corollas and from 0 to 9 disk flowers (figure 1). Viable achenes are produced mainly by ray flowers and only occasionally by disk flowers. Threadleaf snakeweed usually has 2 or less flowers per capitulum, but only ray flowers produce viable seeds (Lane 1985). Flowering in southwestern deserts usually begins in August and continues until a freeze in early November. In northern latitudes, flowering begins earlier, often in June or July. Under greenhouse conditions, flowering can occur any time of the year. Snakeweed plants may bear a few seeds the first year, but they become more productive in later years. Good crops may occur every year on some sites, but climatic factors, plant age, and insects generally cause wide fluctuations in seed production from year to year.

Figure 1—*Gutierrezia sarothrae*, broom snakeweed: flowering head (**center**); ray (**left**) and disk (**right**) flower with attached achene (adapted from Ruffin 1974).



The achenes from ray florets are brown, roughly cylindrical (about 0.9 to 1.6 mm long and 0.2 to 0.7 mm wide), and weigh about 0.15 mg (figures 2 and 3). The often-infertile disk achenes are smaller than the ray achenes. The achenes are pubescent, with rows of white trichomes appressed to the seedcoat in the direction of the pappus. Upon imbibition, the trichomes radiate outward to draw and retain water next to the pericarp. The trichomes act to anchor the achene and enhance soil penetration (Mayeux 1983, 1989). The

Figure 2—*Gutierrezia sarothrae*, broom snakeweed: longitudinal section through an achene.



pappus consists of small white or yellowish erose scales (<1 mm length) aligned with the axis of the achene. This highly reduced pappus is unlike many members of the tribe Astereae, which usually have a well-developed pappus for wind dispersal (Solbrig 1960). Thus, snakeweed achenes are absent of any specialized structures to facilitate long-range dispersal and most fall directly below the parent on the leeward side (Oshman and others 1987; Wood and others 1997). Dispersal is highest in the autumn (about 60%) and may continue into the following summer or as long as flower bracts remain on the plant. About 91% of the achenes are independently dispersed, with the remainder falling within a portion of the capitula (Wood and others 1997).

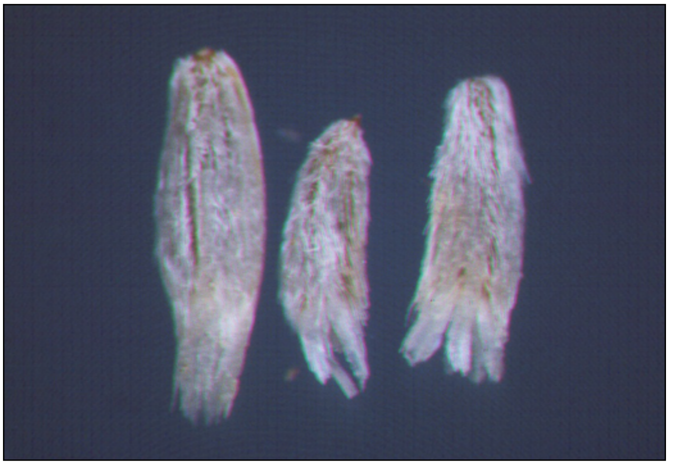
Seed collection and cleaning. A mature plant in autumn can be clipped or pulled from the soil, placed in a paper bag, and shaken to remove most achenes from the capitula. Oven-drying a plant for 48 hours at 50 °C facilitates achene removal and reduces the after-ripening period (Mayeux 1989). Contents after hand-threshing should be pulsed twice in a seed scarifier to further loosen the achenes. A pneumatic seed cleaner with 2 sieves (about 3 and 5 mm round holes) can be used to separate achenes from other flower parts by setting the air blower at 8.0 mm and turning it on twice for about 10 sec/plant (Wood and others 1997). A medium-sized snakeweed plant produces about 4,000 achenes, but this number can vary greatly by year and plant age (Ragsdale 1969).

Seed storage. Snakeweed achenes (figure 3) can be stored in paper or cloth bags under dry laboratory conditions for 3 or more years (Mayeux 1989). They are reportedly dormant at maturity and require a 4- to 6-month after-ripening period unless they are dried soon after collection (Mayeux and Leotta 1981). Under field storage, achenes contained within nylon packets and placed on the soil surface in fall were mostly inviable by the next summer (Wood and others 1997). Similarly, achenes retained in flower bracts and collected biweekly from October to May were tested as more than 50% viable; however, after May viability declined below 10%.

Germination. The after-ripening requirements of freshly collected snakeweed achenes were reduced by exposing them to a continuous temperature of 50 °C for at least 48 hours before laboratory or greenhouse germination trials (Mayeux and Leotta 1981). Dormancy-breaking treatments such as scarification, stratification, and leaching have been reported not to enhance germination (Kruse 1970). Stirring in dichloromethane for 10 minutes increased germination of newly harvested threadleaf snakeweed seeds and stirring in large volumes of distilled water for 24 hours before incubation on filter paper had the same effect (Mayeux and Leotta 1981). Tests show that optimal germination in greenhouse pots occurs when achenes are sown on the surface or pressed lightly onto the soil and maintained at a 15 to 25 °C alternate temperature regime, a minimum of 8 hours of light, and soil saturated and subsequently maintained at a soil water potential above –300 kPa for at least 5 days (Kruse 1970; Mayeux 1981; Wood and others 1997).

Field practice. Because snakeweed is toxic to livestock and sometimes to wildlife, competes with more desirable forage, and offers limited soil erosion protection, it is usually not considered a beneficial species for seeding rangelands. It might be considered for use on land under reclamation. Although we found no studies to confirm this, we anticipate that sowing seeds extensively on an exposed soil surface in early spring when daytime temperatures are near 20 °C offers the best potential for propagation.

Figure 3—*Gutierrezia sarothrae*, broom snakeweed: achenes.



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Fabaceae—Pea family

Gymnocladus dioicus (L.) K. Koch

Kentucky coffeetree

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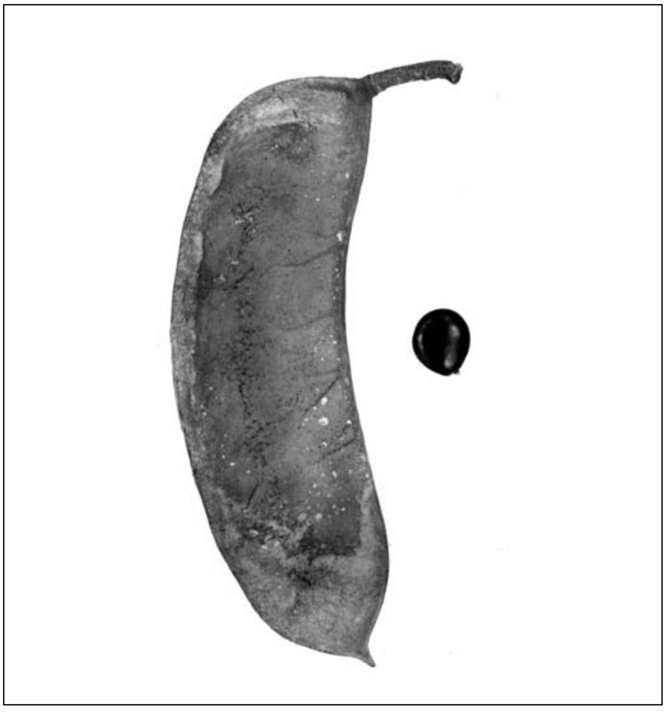
Growth habit, occurrence, and uses. Kentucky coffeetree—*Gymnocladus dioicus* (L.) K. Koch—is a medium to large deciduous tree that occurs naturally in rich bottomlands from New York, Pennsylvania, southern Ontario, and Minnesota, southward to eastern Nebraska, Oklahoma, eastern Kentucky, and Tennessee. The only other species of *Gymnocladus* is native to central China (Sargent 1965). The tree grows to heights of 23 to 34 m and bole diameters of 60 to 90 cm. Kentucky coffeetree is used chiefly as an ornamental and also to some extent for posts and crossties (Harrar and Harrar 1946). Rehder (1940) reported that the species was introduced into cultivation prior to 1748. It has been reported that early settlers of Kentucky and Tennessee used the seeds as a substitute for coffee and the pulp of the green fruit in medicines (Harrar and Harrar 1946). There has been some research into the insecticidal properties of certain unusual amino acids isolated from the seeds (Rehr and others 1973; Evans and Bell 1978).

Flowering and fruiting. The greenish white, dioecious flowers appear in May and June (after the leaves) and are borne in terminal racemose clusters. The fruit is a tardily dehiscent, flat, thick, woody legume (pod) that ripens in September or October and usually persists unopened on the tree until late winter or early spring (Van Dersal 1939). The dark brown or red brown legume is 15 to 25 cm long, 2.5 to 5 cm wide, and usually contains 4 to 8 dark brown or black oval seeds separated by a mass of dark, sweet pulp (figures 1 and 2). The seeds are about 2 cm long with a very hard and thick seedcoat. They will generally remain in the legume until it falls and is broken up by decay, a process that may take 2 years or longer (Harr 1927; Sargent 1965).

Collection of fruits; extraction and storage of seeds. The fruits can be collected at any time during the late fall, winter, or spring by picking them from the tree or from the ground. Sometimes the legumes can be dislodged by vigorously shaking or flailing the branches.

The seeds may be extracted from the fruits by hand or with mechanical macerators or threshers (see chapter 3). The number of clean seeds per weight ranges from 440 to 600/kg (200 to 300/lb) and averages 500/kg (230/lb). Purity of seedlots is almost 100% and 90 to 95% of the seeds are usually sound (Sander 1974).

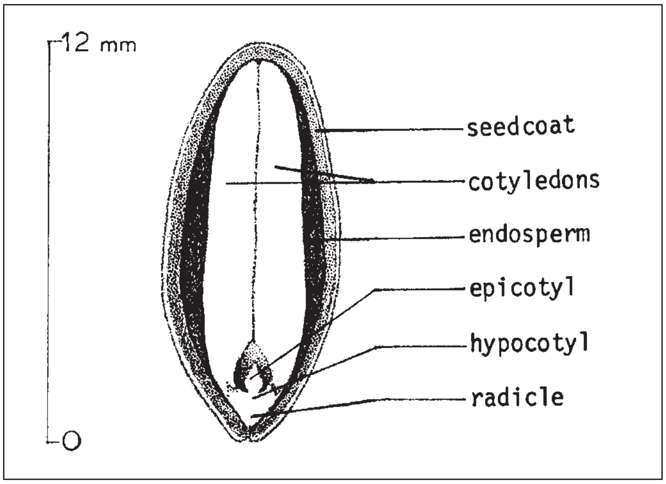
Figure 1—*Gymnocladus dioicus*, Kentucky coffeetree: legume and seed.



There are no long-term storage data for seeds of Kentucky coffeetree, but like other Fabaceae of the temperate zone, storage is not difficult. Dried seeds should be stored at near- or below-freezing temperatures. Short term storage (overwinter) has been successful under these conditions (Weisehuegel 1935), and storage for much longer periods should be possible also.

Pregermination treatments. Kentucky coffeetree's hard, impermeable seedcoat normally requires scarification for timely germination. The best results have been obtained by treating the seeds with concentrated sulfuric acid for

Figure 2—*Gymnocladus dioicus*, Kentucky coffeetree: longitudinal section through a seed.



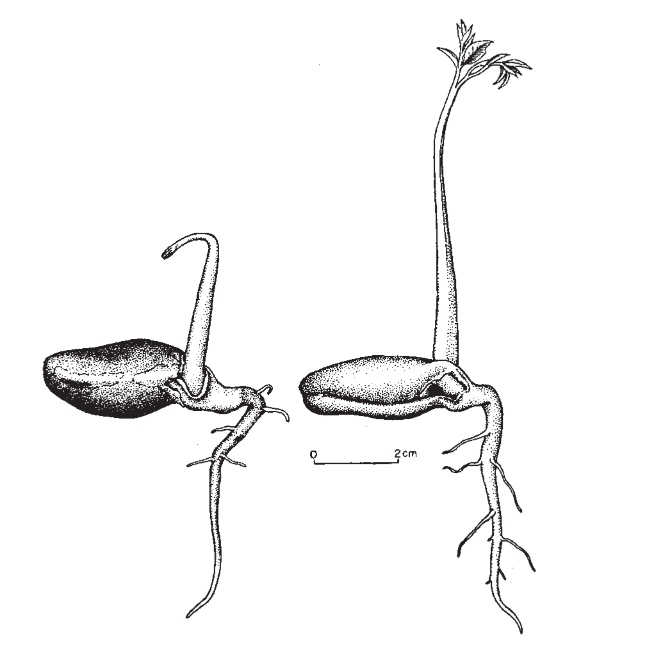
periods of 2 to 4 hours (Liu and others 1981; Dirr and Heuser 1987). Seeds from one source in southern Minnesota germinated 80% without acid treatments, and acid did not improve that performance (Ball and Kisor 1985). When treating large lots of seeds, it is best to do time trials with small samples to determine the soaking period that gives complete imbibition without damaging the seeds. After the acid soak, the seeds should be thoroughly washed to remove any remaining acid before planting. Other precautions on the use of strong acids for seed scarification are found in chapter 5.

Germination tests. There are no official test prescriptions for Kentucky coffeetree seeds, but germination can be tested easily. Samples of scarified seeds should be incubated in flats of sterile sand or on paper media at alternating temperatures of approximately 20 °C at night and 30 °C in the daytime (Sander 1974). For such small numbers of seeds, cutting or filing through the seed coats may be used in place of acid scarification. One test in sand gave 86% germination in 30 days (Sander 1974). Dirr and Heuser (1987) reported that 93 to 100% germination should be achieved. Germination is hypogeal (figure 3).

Nursery practice. Pretreated seeds should be sown in the spring in rows spaced 45 to 75 cm (18 to 30 in) apart, depending upon irrigation and cultivation methods. Even closer spacing can be used, but rows should be no closer together than 15 cm (6 in). The sowing rate should be 40 to 60 seeds/linear meter (12 to 18/ft) with the seeds covered with about 2.5 cm (1 in) of firmed soil (Phillips 1931; Engstrom and Stoeckler 1941). In general, about 60 to 75% of the seeds sown will produce plantable seedlings. Seedlings may be planted in the field after 1 year (Sander 1974).

Kentucky coffeetree may also be propagated by cuttings taken in December to March (Dirr and Heuser 1987).

Figure 3—*Gymnocladus dioicus*, Kentucky coffeetree: seedling development at 2 and 54 days after germination.



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